



Socio-Economic Benefits from the Use of Earth Observation

Report from the International Workshop held at Joint Research Centre, Ispra
11-13 July 2011

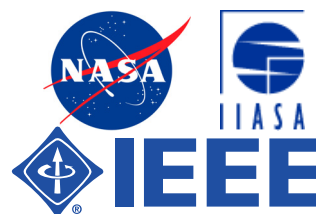
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LIST OF ABBREVIATIONS

EO – Earth Observations
FEWS – Famine Early Warning Systems Network
GEO – Global Earth Observation/Group on Earth Observation (depending on context)
GEOSS – Global Earth Observation System of Systems
GSDI – Global Spatial Data Infrastructures Association
GIKN – Geographical Information Knowledge Network
ICSU – International Council for Science
IOC - Intergovernmental Oceanographic Commission
NRC – National Research council
PSI – Public Sector Information
RS – Remote Sensing
SEB – Socio-Economic Benefit
SLR – Satellite Laser Ranging
SME – Small Medium Enterprises
SDI – Spatial Data Infrastructure
TC – Transaction Costs
UNEP – United Nations Environment Programme
UNFCCC - United Nations Framework Convention on Climate Change
Vol – Value of Information
WMO – World Meteorological Organisation

EXECUTIVE SUMMARY

The aim of this document is to report on the workshop on “Socio-economic Benefits of Earth Observations” held at the Joint Research Centre of the European Commission, Ispra, on 11-13th July 2011. This workshop has been conducted as part of GEO Task US-09-02a: “Socio-Economic Benefits of GEO and GEOSS”, led by NASA, the International Institute for Advanced Spatial Applications (IIASA), and the Joint Research Centre of the European Commission (JRC). It was organized by these three organizations, and by the Institute of Electrical and Electronics Engineers (IEEE).

Twenty-five experts from America, Europe and Australia have gathered in Ispra to present their experience in the field of the evaluation of the benefits from Earth Observations obtained by in-situ, remote and the new citizen’s sensors.

The discussion was based on the outcomes of two previous workshops held in 2010 on the same issue, in US and in Europe. The background section presents the rationale behind the need of understanding the benefits Earth Observations, supported by several initiatives at the continental (e.g. INSPIRE Directive in Europe) and at the global (e.g. GEOSS) level.

The aim of the workshop, described in the second section of this document, was to support the development of international capabilities to determine, quantify and document the socioeconomic benefits from EO and their use, and to jointly develop a programme of activities to be followed in the next few years by the research group.

The foreseen activities of the programme were the consolidation of the body of literature in the field, the collection and analysis of suitable methodologies to assess Earth Observations’ benefits, and of evidence of benefits from existing case studies, the development of appropriate outreach initiatives, the strengthening of the existing community of researchers and the link with other communities of scientists, to set up multidisciplinary studies.

To this aim, each participant brought his/her own experience in the analysing and assessing the impacts of Earth Observation in their own field of research, generating an interesting list of multifaceted examples and case studies in which the same problem is analysed from different perspectives. Section 3 contains a summary of each presentation, which gave the elements for the subsequent discussion among experts, leading to the preliminary programme of activities. Among the several subject of discussions there were the value to be ascribed to Earth Observation data, the need of complementing ex-ante impact assessments with monitoring and ex-post evaluations, the need of clearly communicating the benefits to policy makers in order to fund research and as well to provide a service to the society. These discussion topics are summarised in section 4, describing also the view of the experts as regard possible activities for the creation of a body of knowledge about the field, for the definition of a methodology for the estimation of Earth Observations’ benefits, the criteria for selecting suitable case studies to show such benefits and proposal for outreach and dissemination activities.

As final recommendations from the workshop, priority should be given to:

- the development of an accepted scientific paradigm and of a General Economic Framework to measure EO costs and benefits;
- the establishment of a community of practice bringing together demand and supply;
- the support to increase the number of researchers active in this field research group;
- the showcase of concrete projects clearly communicating the benefits achieved.

Moreover, concrete suggestions were given aimed at developing research activities to establish a consolidated state of the art, mainly consisting in meta-analysis of existing studies and production of high-impact articles or special issues in well-recognised scientific journals.

1 BACKGROUND

The benefits from improving Earth Observation (EO) have been the subject of decades of research and discussion. The need for understanding environmental dynamics is even more urgent now given the recognized issues of climate change, sustainable food sources and increased need for energy. Scientists are increasingly being called upon to provide impartial scientific information to support decision-makers (ICSU, 2011). The importance of science in informing societal decisions is driven by at least two factors: (i) a new recognition that there are significant global impacts of decisions made at national levels and (ii) the complex and non-linear nature of environmental driving functions that make optimization of outcomes less intuitive. Events like the 2012 United Nations Conference on Sustainable Development (Rio +20, <http://www.uncsd2012.org/rio20/>) and the preparatory Planet Under Pressure Conference (<http://www.planetunderpressure2012.net/>) are the sign that the scientific community is trying to follow these principles. This leads to the need for more observation-derived information for scientists, decision makers and the public, and ways to increase their appreciation of the value of such information.

In addition, there is greater attention to performance of government programmes and to the benefits and impacts of public investments. Pure science is no longer a sufficient justification for large, expensive observing systems, such as Earth observing satellites, or in-situ monitoring networks. There is a need for applications and tangible, identifiable near-term uses to help justify the observing systems across sectors and stakeholders (NRC 2007a). There is also an increasing pressure to find and demonstrate innovative and practical uses of all Public Sector Information to support policy, business, and management decisions of public and private organizations. While there have been successful examples of applications, efforts to substantiate the benefits of these examples have been limited, especially in their ability to provide a quantitative determination of value and impacts. One could argue that the capability to determine and communicate the benefits is strategically important to make the case for significant additional investments in observing systems and research, attract private sector investments, and enable economic opportunities. Space and other government agencies are therefore concerned with the assessment of benefits to justify the increasing budgets required for comprehensive missions such as GMES, Galileo, Landsat, and other large-scale data gathering for environmental monitoring, in areas such as hydrology and ocean monitoring.

There have been recent efforts to address the collective need for more coordinated EO based on interoperable data and systems, and for interdependence in an economic and environmentally connected planet. Most notably, the Group on Earth Observations (GEO) was created in 2005 to address these collective needs for greater availability of data, interoperable systems, and more comprehensive global data sets, particularly those requiring multi-disciplinary collaborations. GEO is a voluntary partnership of governments and international organizations coordinating efforts to build a Global Earth Observation System of Systems, or GEOSS¹. At the midpoint of the GEO 10 year development cycle (2005-2015), it is becoming increasingly important to develop a framework to identify the benefits to society, science, and the taxpayer of the investments made to develop GEOSS². Similarly, bringing together the multiple satellite systems into a series of coherent constellations and the inclusion of more nations' EO systems will be leveraged by understanding the applications, impacts and benefits of global scale collaborations.

¹ As of March 2011, GEO's Members include 86 Governments and the European Commission. In addition, 61 intergovernmental, international, and regional organizations with a mandate in Earth observation or related issues have been recognized as Participating Organizations.

² A tangible need for this framework is to enable GEO Members to decide if transition of the information system beyond 2015 to an operational and sustainable system is to occur.

With these considerations in mind, the purpose of the workshop was to identify a programme of activities for 2011-15 to support the development of international capabilities to determine, document, and quantify the social, environmental, and economic benefits from EO and their use, including the benefits that can be achieved by GEO and other international bodies.

The workshop built on an increasing body of literature in the fields of EO, geographic information and related systems (GIS), and (spatial) data infrastructures. This literature is framed by the economic and social science domains that have considered the value of information for decision-making at the level of the individual, the firm, or society at large³.

In Europe a major impetus towards the assessment of spatial data infrastructures (SDI) has come with the development and adoption of the INSPIRE Directive in 2007, a European legal framework requiring all 27 member states of the European Union to establish and maintain SDIs for their jurisdictions, and make them interoperable through the detailed technical specifications being developed under the guidance of the JRC. A study on the expected economic impact of INSPIRE was carried out in 2003-2004 prior to the adoption of the law (INSPIRE FDS and Craglia, 2003, Dufourmont, 2004). Given the dearth of published literature at the time on the costs and benefits of SDIs, the JRC launched a programme of research to fill the gap. This programme is still in progress and has yielded some interesting results, largely validating, so far, the assumptions made in 2003 (Craglia and Nowak, 2006, Garcia Almirall et al., 2008, Craglia and Campagna, 2010, Craglia et al., 2010). In parallel, progress in over 30 European countries on the implementation of SDIs has been reported in a set of studies by Vandenbroucke and Janssen (2008), while Crompvoets et al. (2008) have collected a range of theoretical perspectives informing the work on SDIs.

GEO-related and remote sensing focused work have been carried out by Obersteiner, Fritz and colleagues at IIASA in the context of the GEOBENE project (<http://www.geo-bene.eu>) (Fritz et al. 2008, Smirnov and Obersteiner 2010, Rydzak et al. 2010), and more recently in the EuroGEOSS project (www.eurogeoss.eu). In the latter, a range of methodologies has been deployed to capture the multiple facets of the potential benefits of GEOSS. These include surveys of stakeholders and users of thematic data in the fields of forestry, drought, and biodiversity, surveys of GEO members, and analysis of the data with a range of methods including Bayesian decision theory, Value Measuring Methodology, Real Options Framework/Portfolio Theory, and the use of Global Model Cluster and System Dynamic Models (McCallum et al. 2010). A collection of the key literature (77 entries at the time of writing) related to benefit assessment of remote sensing and spatial data infrastructures has been assembled by the team working in the GEOBENE and EuroGEOSS projects and is available at <http://lyra2.felis.uni-freiburg.de/eurogeoss/>

Taking a broader perspective one could argue that geographic data infrastructures, including GEOSS, are a subset of information infrastructures, and one should therefore also look at the experiences and lessons learned in other fields such as health (see for example Hanseth and Monteiro, 1998), or e-government projects, which also have a growing body of literature on assessment methods (see for example Codagnone et al., 2006, OMB, 2011).

Related fields focus on the role of Information and Communication Technology (ICT) to foster innovation, productivity and efficiency gains (see for example: Brynjolfsson and Hitt, 1996, Bannister, 2001, Atkinson, 2004, Jansen et al., 2005), to signal modernity, efficiency,

³ Examples of GI-related work include Smith and Tomlinson (1992), Onsrud and Rushton (1995), Price Waterhouse (1995), Bernknopf et al (1997), Gillespie (2000), Nedovic-Budoc and Pinto (2000), Baltimore County (2001), Halsing et al. (2004), Booz Allen Hamilton (2005), Rodriguez-Pabon (2005), Blakemore and Craglia (2006), Grus et al. (2007), Longhorn and Blakemore (2008), Crompvoets et al. (2008). Meta reviews of literature in this field have been carried out for example by Lance et al. (2006), Genovese et al. (2009), Richter et al. (2010).

and competence (Feldman and March, 1981), to interact and be shaped by the social milieu in which it is deployed (see for example Kling, 1999, Kling, 1996), or how ICT is key components together with people, in the process of negotiation and alignment taking place in organisations (Actor Network Theory) (De Man, 2011).

A complementary perspective focuses more on the content of data infrastructures, i.e. data and information in general or Public Sector Information (PSI) more specifically. The latter has recently attracted considerable interest as the opportunity to open up the vaults of PSI held by government agencies is seen as a boost for democratic accountability but also for business to create value added products and foster innovation and job creation (see for example: Fornfeldt et al., 2009, Dekkers et al., 2006, ACIL Tasman, 2008, Uhler, 2009).

The benefits derived from improved environmental information come from decision making from personal levels through regional, national and intercontinental scales. Since the decisions and their impacts are based on the societal milieu and constraints of the decision maker, factors and impacts (i.e. benefits) are not uniformly assignable without context. Therefore, the assessment of benefits requires the adoption of a broad multi-disciplinary approach. Against the background of these considerations, two workshops held in 2010 provided additional context to the activities planned for this meeting in 2011.

The “Value of Information” Workshop was held on June 28-30th 2010, at Resources for the Future, Washington DC (US), with the support from NASA, Resources for the Future (RFF), and RFF’s Centre for Disease Dynamics Economics and Policy. The workshop brought together experts from the space and earth science domain, and the public health and social science community. The participants addressed the key issue of the value of information, and methods to measure it. A report of the workshop (Macauley and Laxminarayan, 2010) identifies the key outcomes.

In respect to value, the participants agreed that value denotes a quantitative measure, although not necessarily expressed in monetary terms. The advantage of having a quantitative measure is to provide a reference system to facilitate comparison, and therefore the choice, of alternative projects for decision makers. When it is not feasible to express a value in monetary terms, this can be given in the form of other measures, like number of lives saved, improvement in the quality of the environment or increased efficiency. The participants identified some criteria by which information has value. In their view, the most value is realised when:

- Information makes decision makers indifferent towards alternative choices
- Actions can be taken in response to the information
- The consequences of making the wrong choice is large
- The constraints on using the information are few
- The cost of using the information is small.

On the basis of the presentations discussed at the workshop, five main methodological approaches were identified to ascribe value to information:

1. *Price- and cost-based derivation*: the value of the information can be derived, and therefore expressed in monetary terms, from the insurance premium or cost avoided. This approach was used for example to value EO data to forecast disease outbreaks based on avoided control costs, reduced mortality and averted disruption of trade.
2. *Bayesian belief network*: it is a conventional statistical approach according to which people’s expectations are updated when new information is available. This framework has been used to derive the value of EO data about expected temperature mean and variance in a changing climate.

3. *Regulatory cost-effectiveness*: people are willing to pay to avoid loss of information or direct cost savings are achieved when a regulatory framework is in place. This approach was used to quantify the cost savings of implementing the land use and water quality regulation thanks to EO data products.
4. *Econometric modelling and estimation*: relationships between information availability and people's decisions are estimated with econometric modelling. For example, this approach was used to identify the value of diagnostic tests for malaria taking into account behavioural responses of patients in seeking additional treatment based on their age and income.
5. *Simulation modelling and estimation*: flow charts are used to model how the same information is used for various purposes. This method was used to show, for instance, how EO data on land use provide inputs for carbon assessment. The value of improved land carbon assessment can be linked to the trading prices of carbon according to the European Union Emissions Trading Scheme.

The workshop provided experts in the space and healthcare fields with the unique opportunity to discuss and present new applications and methodologies of information value. In particular, the event was an opportunity to advance a common vocabulary across social and Earth science, forming a new community of practice. The workshop also identified ways to improve the design and evaluation of value-of-information studies, and concluded that "Funding this line of research in pilot projects could serve to prototype and pave the way for more routine integration of value-of-information studies in science-based and applied-science research. In turn, these efforts would better enable realization of the social benefits of the research" (Macauley and Laxminarayan, 2010, pg. 6)

The "GeoValue" workshop was held at HafenCity University in Hamburg on 30th September-2nd October 2010, and was organised with the support of HafenCity University, the Association for Geographic Information Laboratories in Europe, the Joint Research Centre of the European Commission, and the University of Laval, Canada. The workshop focused on the value of geo-information, the assessment of Spatial Data Infrastructures, the socio-economic aspects of geo-information, and quantitative methods and models for impact assessment (presentations and proceedings are available at <http://digimap.hcu-hamburg.de/geovalue/>). A previous workshop on GeoValue was held in Hannover in April 2009⁴.

There are clear areas of similarity and complementarity with the substantive and methodological issues discussed at the June 2010 workshop in Washington, DC. In respect to the discussion on value, Longhorn (2010) highlighted a number of key issues that make it extremely difficult to assign a value to geo-information, or any other digital information, as the value varies with application, user, context, time, and it is also becoming increasingly complex to disentangle the value of the data with that of the service or application delivering them to the user.

In particular, there were overlaps in respect to the Regulatory framework and Modelling approach (points 3 and 5 above). Two additional perspectives related to:

1. *Transaction cost*: These are costs incurred when making an economic exchange (Williamson, 1985) and also apply to the geographic information market. Looking for (geo)information or (geo)product requires time in order to find the right dataset and acquire the best available product for the best price. This theory was used to understand how much allegedly "free" geo-information really costs users.
2. *Volunteered geographic information (VGI)*: This approach was used to explore if the new phenomenon of VGI may change the way to assign value to spatial data and to

⁴ Key papers from that workshop are published at <http://ijsdir.jrc.ec.europa.eu/index.php/ijsdir/issue/view/20>

the business models supporting the production of spatial data. This is an interesting new development in that users become also producers of information and of potential value added.

An interesting discussion followed the keynote by Frank (2010) who reviewed the evolution of thinking in economics through the work of eight Nobel Prizes. Frank showed a shift from pure rationality based on perfect information (Samuelson), to the recognition of uncertainty and bounded rationality (Simon), transaction costs (Williamson), as well as a change in focus from the individual to the firm (Coase), regional dynamics (Krugman), institutions (North), society (Sen) and the global commons (Ostrom). In other words, economists seem to recognize the increasing complexity and inter-relatedness of human endeavours, and hence of decision-making. Yet when it comes to valuing information, several approaches go back to focusing on individual decision-makers, and assume an almost linear relationship between the quality and quantity of information available and the quality of decisions (i.e. better information leads to better decisions), which is at the very least debatable in the face of both theory and practice.

The workshop demonstrated considerable attention to the variety of users and contexts of (geo) information. The workshop called for more in-depth research on the role of information and related products in real life situations, a much more transparent articulation of the assumptions made so that they can be verified over time, and a greater sharing of experiences in a variety of settings among different communities-of-practice to make more rapid progress in this important field.

2 OBJECTIVES OF THE WORKSHOP ON THE SOCIO-ECONOMIC BENEFITS OF THE USE OF EARTH OBSERVATIONS

The previous section has highlighted the wide range of theoretical perspectives and methodological approaches to assess and measure the value of data/geo-information/technology/system/infrastructures (depending where the focus is). We are not short of ways to attack the problem but the solid evidence of benefits remains elusive.

Much of the work reviewed in the many studies for which references are provided (which is only a small part of the total) attempts to assess benefits ex-ante at the time when funding is needed by sponsoring agencies. Many assumptions are made, and the more complex the method, the greater the number of assumptions, which are often not explicitly stated and are not verified subsequent to obtain the funding.

Some assessments occur at the end of a project, trying to ascertain the impact and value of the data and information used or process improvement in decision-making. With forethought, projects can design and include an approach to collect appropriate metrics. However, if such an approach is not designed or not used, then projects must make assumptions and construct counter-factual arguments. Even still, the ability to isolate and identify the impact attributable to new data, information, or process is difficult. Moreover, funding organizations may require assessments of socioeconomic benefits and impacts as part of a project. However, project leaders and staff may not have sufficient skills for designing a study, or knowledge of how to solicit and acquire the services needed.

Many other studies that have taken place during the course of implementation (for example at the time of 5-year reviews) seem to be based on methodologies like Performance Based Management or Balanced Scorecard (e.g. Cromptoets et al., 2010; Toomanian et al., 2011), that measure the extent to which the objectives set by the system/infrastructure/initiative/ or project have been met in time and budget. This is a helpful management methodology but the focus is on internal performance and outputs, rather than benefits and outcomes. Much more work is therefore needed to assess benefits beyond the organization, to include users

and society at large⁵. Capabilities are needed at a) the micro-level, such as individual projects; b) the mid-level, such as programmes' portfolios of projects; and, c) the macro-level, such as national observing systems or international efforts, such as GEO.

As we recognise the need to focus more and more on the variety of users of EO and related systems, it becomes critical to identify these users. However, in the age of ubiquitous Internet access through multiple devices, user identification at the global level respecting privacy, confidentiality and national laws and customs is challenging. How do we frame therefore a research activity to find users, elicit their views of change, and the value they place on that change? How do we relate such change with the advancing work in EO analyses and related information systems and infrastructures? How do we account for the variety of users and uses that go beyond our simplistic models of decision-making?

As noted above, the workshop objective was to support the development of international capabilities to determine, quantify and document the socioeconomic benefits from EO and their use.

The programme of activities that was discussed includes the following items:

- The consolidation of dispersed bodies of literature relevant to the assessment of impacts and benefits of geographic information/earth observation;
- The evaluation of different methodologies appropriate to undertake such assessments;
- The gathering of evidence of impacts/benefits in different user communities and societal benefits areas;
- Connections between physical, social science, and economic communities to enable joint studies, applied projects, and research;
- Development of capabilities and networks for intelligent solicitation and acquisition of socioeconomic benefit analysis services;
- The identification of demonstration exemplars and use cases that can be cited for further development and analyses;
- Outreach activities to develop shared understanding across disciplinary boundaries on value and methods of assessment.

The workshop has been jointly organised by JRC, NASA, IIASA and IEEE, hosted at JRC in Ispra (Italy), where 22 experts gathered from Europe, US, Brazil, Australia, from varying disciplines such as sociology, climate modelling, economics, geography, data systems experts (see list of contributors at the end of the document).

This report is structured as follows: In section 3, contributions by participants are synthesized, based on the presentations delivered. The experts focused on the description of their perspectives and experiences and on the proposal of items and priorities for the programme of activities. Section 4 describes the main topics that animated the debate of the discussion sessions and of the workgroups. From them, priority items and concrete proposals for the 2011-2015 programme of activities, to be undertaken by researchers on value of EO, are summarised in section 5.

⁵ GEO focuses on Societal Benefit Areas in part to address this benefit assessment and articulation.

3 CONTRIBUTIONS BY PARTICIPANT EXPERTS

3.1 A Tale of Two Teams: Bringing Together Data Curation and Interdisciplinary Groups - Challenges and Benefits (*P. Romero-Lankao*)

The research project “Resilient and Sustainable Cities” (RS-Cities) is based on the assumption that cities are key drivers of climate issues but also sources of responses, which are not always effective. For this reason, the project RS-Cities seeks to contribute to a deliberate and transformative urban transition by conducting interdisciplinary research with cutting-edge modes of scientific inquiry about the multi-scale processes shaping urban (i) emissions, (ii) impacts, vulnerabilities and sustainability/resilience, and (iii) capacities to respond (governance).

The goal of RS Cities is to identify fundamental causes and patterns of vulnerability/resilience unique-to and shared-by cities as diverse as New Orleans, Lusaka and Santiago.

The keyword is “user-inspired basic-science” aimed at passing from the many studies at the city level and scale up, to understand global processes, as opposed with the standard downscaling, that analyses from global modelling to local scale.

Many social scientists work with qualitative data, from which data can be captured differently. To see potential impact at the urban level, we need to know the hazards for climate changes, explored by physical (and social) scientists by means of exposure and sensitivity methods.

The project makes use of the concept of *meta-knowledge research* (Evans and Foster, 2011), that analyses many case-studies to uncover patterns/correlations/regularities in scientific claims; it infers beliefs, preferences, methods, tools, data, and uses meta-analysis and systemic reviews.

The project has developed a meta-framework on dimensions/determinants of urban vulnerability, identified main lineages and it is currently in the phase of defining the narratives of causation and the data-curation requirements. Main findings so far include the consideration that urban vulnerability is a multi-faceted and wicked problem, and that there are discrepancies of existing approaches as regards focus, definition of key terms, methods, policy implication, and data practices.

In particular, data need to be captured on many dimensions (or sectors) and on different spatial and temporal scales. At the intersection between “data curation” and “data conservation” (see Figure 1), the following issues have been identified:

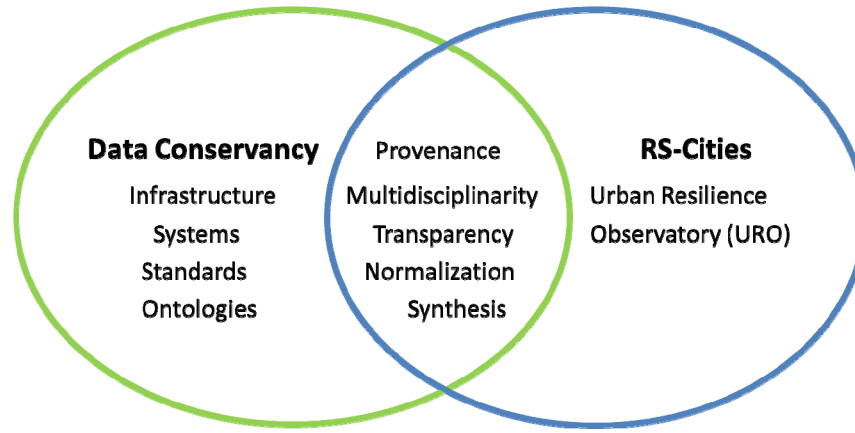
- Data provenance and preservation problem, looked at by means of about 170 case studies including hundreds of datasets, characterised by uncertainty regarding data preservation and accessibility;
- Transparency problem: with missing data and different scales of analysis, science is not reproducible;
- Interdisciplinary data problem: few consistent and compatible protocols and tools due partially due to multi-disciplinary nature of the data;
- Integration and synthesis problem: variations in data, methods and framing practices; semantics problems, such as definitions, e.g. population density, city boundaries, GreenHouse Gases scopes; data organization, in terms of schemas, structures, metadata, accessibility.

The Urban Resilience Observatory (URO), set up by the project, proposes therefore:

- Meta-analysis and meta framework tool, to provide a means by which researchers can classify, partition, compare or integrate studies and research artefacts, and to help understanding how case studies are built (semantics, interoperability issues);
- Data synthesis tools, to select, integrate, and transform heterogeneous data in order to support subsequent analysis;

- A decision support tool, aimed at an audience of policy makers and their related research or decision-making staff, to help them allocate the limited resources available.

Figure 1 Intersection between Data Conservancy and RS-Cities project.



In conclusion, this emerging area of science requires data from different sources, which are heterogeneous and incompatible and a network of researchers that can explore emerging concepts, ways of data integration and reuse. In addition, in order to inform operational decision-making such data should be integrated and synthesized. These challenges may only be addressed in a permanent collaboration between data experts and scientists (users, decision-makers and sponsors).

3.2 Value of Information from GEOSS: the Systems' Challenge (*M. Obersteiner*)

World in 21st century is characterised by globalisation, sectoral integration and resource scarcity, as well as by challenges and risks which seem unprecedented, in regard to their magnitude, hazard type, frequency, and mutual relationships.

For example, UNFCCC⁶ objective of choosing an atmospheric concentration, which allows for the adaptation of eco-systems, food security and economic development, is hindered by the high uncertainties related to the climate target, by the challenges of a Global Energy Portfolio and of the allocation of renewable energy in the future, but also of reducing areas suffering from hunger and malnutrition, and allow a more equal distribution of land.

Earth is nowadays the object of one grand planetary experiment, which humans are making without learning, because they have to date not built any monitoring systems to learn. It would be indeed interesting to think about a Tipping Point⁷ Early Warning System (Lenton et al., 2008, see Figure 2). Thinking about future scenarios, the world will be *one* world of change, as governments will continuously be asking for information; scientists will have to pass from unconscious learning to conscious learning. Because observations systems need almost 20 years to be designed, tested, implemented, the time to start their design is now.

Data for international cooperation are therefore needed and from this basis GEOSS finds its main motivations, as idea for *one* world.

Challenge of GEOSS is in particular to assess the impact of changes in observation systems on nine Societal Benefit Areas. To this aim, the GEOBENE project has tried to build a value chain for observation system, based on the cost-benefit ratio.

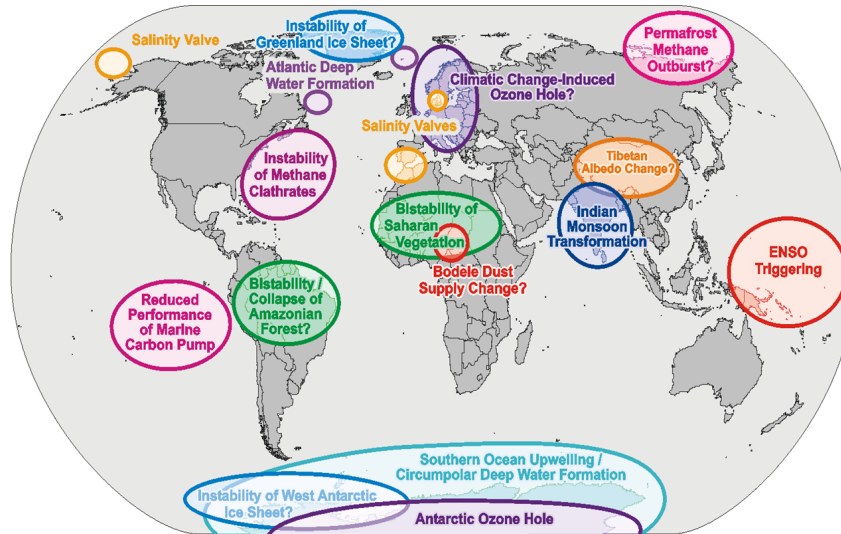
There are two modes of cost-minimised production of Value of Information, which may be found within the GEOSS rationale:

⁶ United Nations Framework Convention on Climate Change.

⁷Tipping Points "refers to a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system" (Lenton et al, 2008)

1. the Global Cooperation scheme calls for “economies of scale”
2. the System of Systems’ view requires “economies of scope”

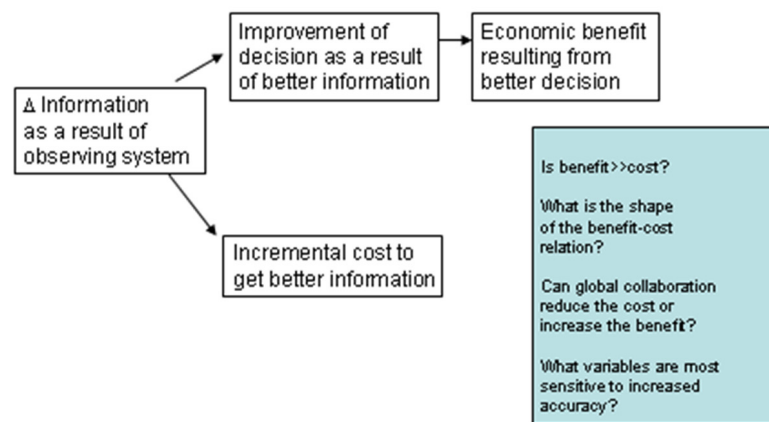
Figure 2 Tipping Points on Earth (source: Lenton et al., 2008).



From the technical side, GEOBENE has proposed a value chain for Observation Systems (Figure 3) and different case studies showing how improvement of decisions may be achieved:

- improvement through higher spatial resolution;
- improvement through higher temporal resolution;
- improvement through better integration of satellite and in-situ EO Systems;
- improvement through better models, informed by observations.

Figure 3 Building a value chain for Observation systems (source: GEOBENE).



In conclusion, despite that the high value of information has been clear for millennia, despite the fact that EO technology and data storage are available, and that we know how to do it and how to produce cost effectively, still there are difficulties in gaining value from it, because System of Systems and Global Cooperation are “socially very difficult to produce”. In this context, Value of Information studies might help in solving the social dilemma.

3.3 Measuring What We Value and Valuing What We Measure (*M. Macauley*)

The challenge of assessing benefits of EO has been dealt with, until now, through collection of anecdotes in varying form of publications, from strategic documents, to technical reports and scientific publications (NASA, 2009, National Research Council, 2007a, 2007b, US Office of Science and Technology Policy, 2010, Macauley and Laxminarayan, 2010).

These usual approaches for describing the benefits are varying in quality and have had limited outreach so far. There are few compendia, which are almost collection of studies, and lack of best practices, of general guidelines and of a systematic collection and accessibility of findings. Efforts do not seem to be well coordinated, and the credibility is reduced for this reason. Little has been done in order to solve the conceptual problem of defining information and isolate the value of the information itself. Part of this can be attributable to limited incentive to research in this field, beyond peer review publication and funding agency's reporting requirements. In addition, valued information seems poorly understood.

William D. Nordhaus, Sterling Professor of Economics, Yale University, writing about the value of weather and climate information, in 1986 said: "We found that Value of Information is not zero, but not enormous either". This means that we should escape from the temptation of considering information valuable anyway, but to introduce more rigour in thinking about Value of Information.

Not all information has value, and it makes sense to ask the questions whether an action be taken in response, if the consequences of a wrong decision based on that information are large, and how costly it is to use the information. On the other hand, the value of perfect information may not justify the cost of its acquisition, but information has value even if it introduces more uncertainty (it reveals that what was thought to be certain may not be), and some attributes of information may confer more value than others.

In other words, the benefit of EO, beyond their intrinsic merit in enhancing science, is a derived benefit. The benefit of information is derived from the values we hold for what the information is about.

EO is about our natural and environmental resources and about human interactions with them. The World Bank, the United Nations, and over 375 international environmental and resource agreements label these resources as part of "the wealth of nations". EO then, – that is, information about this natural wealth – has benefit when it helps us to better manage, enhance, preserve, protect, and use this wealth.

The motivations of identifying the benefits and the characteristics of the audience that will be interested in knowing and using the outcomes of a similar effort, are issues that are worth exploring.

Different methods may be considered for incorporating the value of information, some of them have been already outlined in the background section about the outcomes of the 2010 US workshop on the Value of Information (Macauley and Laxminarayan, 2010).

A possibility to obtain more coordinated efforts for identifying and quantifying benefit of EO could be to put in place a joint initiative, under the same brand, that could be named for example the "VALUABLES" Initiative (Valuing Applications Benefits Linked with Earth Science).

Such initiative should coordinate research efforts in order to demonstrate that information is valued; to ascertain, through the applied research effort, what attributes are required (e.g., spatial, spectral, and temporal resolution, accuracy, precision, frequency, annotation, access); to identify and reduce barriers to use; to identify and lower decision-makers' constraints by enhancing actions that can be taken, increasing the number of people who know about the information, demonstrating that information has value; to use the valuation exercise to think through data, research, partnerships, and assembly of results in a

structured way; to feedback findings into mission design, next decadal survey, and other funding opportunities; to offer guidance for transferability of results and findings; to share findings more widely to audiences beyond the research team and partners.

Figure 4 Matrix for Assessing Benefits (example, from Macauley and Diner, 2007).

	Realized Benefits	Options Benefits*	Knowledge Benefits
Economic Benefits	Entries here are economic benefits conferred, perhaps from data products	Entries here are future benefits	Entries here are new knowledge informing economic benefits
Environmental Benefits	Entries here are environmental benefits conferred, perhaps from data products	Entries here are future benefits	Entries here are new knowledge informing environmental benefits
Public Health Benefits	Entries here are health benefits conferred, perhaps from data products	Entries here are future benefits	Entries here are new knowledge informing health benefits
Security Benefits	Entries here are security benefits conferred, perhaps from data products	Entries here are future benefits	Entries here are new knowledge informing the nation's security interests
Knowledge Benefits	Entries here are data products conferred, perhaps by adding to knowledge	Entries here are future benefits	Entries here are new fundamental science
Note: * Providing an "option" for a benefit to be realized in the future but requiring additional investment; for example, if additional algorithms were to be developed or if the mission and/or instrument were extended (perhaps to operational status)			

In the near-term, horizontal activities to be carried out within our community would include:

- Collect successes and results within a "compendia";
- Increase sophistication of use of measurement and evaluation of the benefits: that is, the quality and usability of research findings and the data and tools on which they are based;
- Identify and collaborate with other research communities;
- Identify and standardize best practices and methodologies: what works for which applications and sub-themes (e.g., public health, environmental health, emergency/disasters).

At the same time, vertical actions to be taken to extend success beyond our community would be:

- Design a compendia of benefits and Vol across applications and sub-themes;
- Identify which data attribute(s) seem most highly valued;
- Start with an applications area(s) that volunteers to be a prototype;
- Publish and disseminate to a wide audience.

3.4 EO Benefits as Perceived by the Coastal Community (R. Longhorn)

The marine/coastal community depends almost exclusively on topological, hydrological, meteorological EO – space, aerial, in situ. Also (often) they require access to non-EO data (e.g. demographics, statistics, legislation). We have to integrate these to address many of the most interesting, challenging – and complex – questions, such as: is RS and EO data more valuable than non-RS?

The integration itself may add 'value' to the original information. Actually the marine/coastal community does not seem to be very much interested in the benefits related to the EO data, despite a number of on-going coastal/marine EO programs:

- GOOS – Global Ocean Observing System (IOC, UNEP, WMO, ICSU), which represents systems of regional programmes and the Ocean component of GEOSS;
- EuroGOOS – the European component of GOOS;
- Coastal GOOS (coastal module of GOOS – 2003/2006 – Integrated Global Observing Strategy - IGOS);
- GMES Fast Track Marine Core Service (2007);
- MyOcean (Ocean Monitoring & Forecasting – 2009-2012).

Details of some of these projects are reported below.

The GMES Marine Core service (2007) has impact on climate research, marine environmental protection, extended range and seasonal weather forecasts, marine safety, fisheries and ecosystems management, shipping and offshore industries, civil security (floods, civil protection...), marine environment ecosystems monitoring.

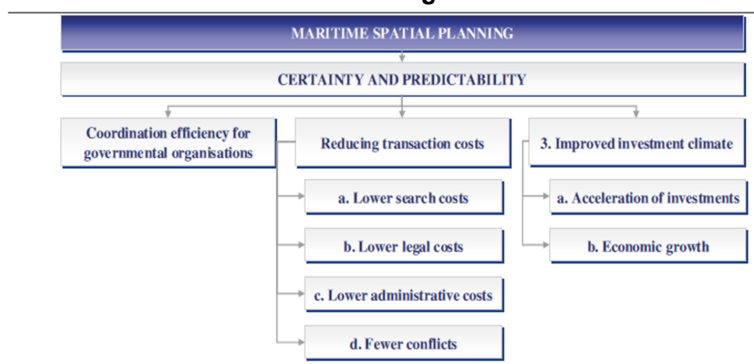
The experience of the Marine Data Infrastructure in 2009 has collected the evidence on costs of marine data collection by public bodies. Analyses have been carried out about the expenditure of public bodies on research vessels, on satellite imaging and about the income gained from sales of raw marine data and from products derived from the marine data and the scaling-up of data costs across the Community. The benefits of reducing uncertainty (over SLR costs in EU) may be classified like the following: € 92 M at 25% reduction in uncertainty; € 183 M at 50% reduction; € 275 M at 75% reduction; € 366 M savings at near complete reduction of uncertainty.

In April 2010, a study of the economic effects of Maritime Spatial Planning has been conducted: in Figure 5 examples of benefits of certainty and predictability are shown.

In September 2010, the EMODnet (European Marine Observation and Data Network) impact assessment identified barriers to the application of marine data, investigating if removing them has a value and how much. It highlighted the factors of competition, as data should be accessible and high prices lead to reduced number of services, and uncertainty, due to lack of marine data infrastructure.

The aim of The Assessment of Ocean Observation Systems (OOS) Value (Canada, May 2011) was to demonstrate innovative technologies, improve co-ordination and collaboration among diverse data sources, develop export opportunities for expertise and technology, ensure economic and safety efficiencies in transportation, improve access to information, ensure data support for a wide variety of applied and theoretical research efforts to better understand, monitor, and manage the marine environment.

Figure 5 Direct Economic Effects of Certainty and Predictability in Maritime Spatial Planning.



The Canadian experience identified as barriers to maximise benefits from OOS: the fact that OOS is project driven, for specific regional needs or issues; that it lacks of an overall national vision (on integration), and therefore implies uncertainty over sustainability (i.e. long-term investment). Moreover, there is a lack of a national framework for OOS, in term of governance, co-ordination, management.

All these projects should have an impact on the debate on the value of the data. There is the need of moving the value/benefit question up the chain to reach the services (built on data). To this aim, we need an agreed framework within which we can assess 'value' from many different perspectives, such as information market (for products and services); economic benefits (data underpinning services which underpin economic development in the coastal zone); societal benefit(s) (which are wide ranging, from urban planning to civil protection, and often non-quantifiable). The value assessment (e.g. as input to a CBA) is tied to the users' specific requirements, therefore, except in an integrated, coordinated programme, the value of the same data to another user is irrelevant to the initial target user. There is the need to engage decision-makers in our debates, to understand how they make decisions based on data that they do not fully understand and thus how they assign value (or not) to these and how their perception changes (with time and experience). This may help also understanding the reasons for funding or not, taking aside emotional decisions made because of lacking data.

3.5 Evaluating the Use of Publicly Funded Science Data for Decisions: Vol Component Analysis (*R. Bernknopf*)

Vol research is about demonstrating why and how scientific data have economic value by informing decisions concerning the social cost and benefit of resource development. Key questions are: what is the value of publicly provided scientific information, can natural science information be integrated with socioeconomic information, can quantitative forecasts about future physical and ecological outcomes be developed to project outcomes associated with different scenarios and, how can uncertainty be understood and reduced to inform decisions with natural science?

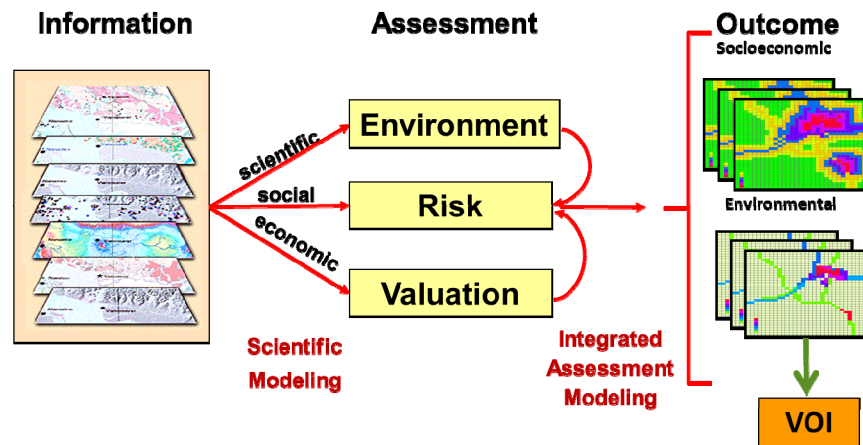
In 2010, a survey has been conducted to identify users, uses and value of Landsat imagery in the US. The sampling of the population was a challenge because there was no list of all users to sample from, therefore the authors used non-probability sampling method called snowball sampling, resulting in a diverse, but not random sample. The respondents were asked about the willingness to pay for Landsat imagery. With a response rate of 53%, the survey indicated that, on average across varying users' typologies, the willingness to pay for a Landsat scene was about 750 dollars.

In the context of this analysis, the value of Landsat imagery in the US was assessed. A case study of the value-in-use was conducted in eastern Iowa that linked earth observations to dynamic earth science models to evaluate the risk of exceeding a nitrate regulatory standard for adverse health impacts. The question addressed was as follows: Can policy makers be better informed with earth observations to evaluate the potential to exceed an USEPA health standard and what would be the economic impacts? In the analysis, economic welfare, the Vol, is improved where earth observations identify areas that can sustain or increase agricultural production while not increasing the rate of contamination of nearby groundwater. An integrated assessment was performed using the moderate resolution land imagery. The study included 35 counties and numerous towns. Furthermore, the study demonstrated the possibility of using satellite data for regulatory analysis and review because the observations provide an archive of the population of land activities rather than a statistical sample. The model covered 9 years worth of data, looking at nonpoint source pollution well catchment zones and crop areas. The economic welfare implications included the regulation of non-point source pollution, potential land use changes to enhance total agricultural production

and value, and the probability of income loss to farmers of exceeding water quality standards. A risk analysis tool is available for analysis of land use portfolio scenarios.

The case study was based on a geospatial decision framework (see Figure 6), i.e. a set of process models and data that integrate natural science information with social and economic models and factors to describe the implications of policy and management decisions, on the basis of a decision with/without the earth observations data. A Value of Information analysis was carried out using a model described in Bernknopf et al. (in press).

Figure 6 The Geospatial Decision Framework adopted.



Potential research directions for analysis of land and resource asset portfolios include input to risk analysis, to economic analysis and to indicators. Economic analysis can benefit from EO because it provides archival thematic data of land change that can be coupled with spatiotemporal/socioeconomic data to measure changes in economic welfare, while climate and land use can change the conditions for access (quality and supply) to natural resources. This is a supply uncertainty that can be input for estimation of option values and transactions costs (data uncertainty and mismatches of resolution). Case studies would be needed to identify and estimate regional comparative advantage. Moreover, EO provides thematic data to develop concentration curves and indexes, and potentially landscape inequality indicators, and to estimate models of decomposition of an ecosystem service concentration index with Poisson and negative binomial regression models.

Examples of these research directions are a Land Use Portfolio Model (LUPM) risk-analysis tool (Taketa et al., 2010, Dinitz et al., 2009, Bernknopf et al., 2006), to help communities make decisions about mitigation investments in a Land Use/Land Cover portfolio regarding potential losses from natural and environmental hazards. The computer tool was tested at a workshop held in Padang, Indonesia, where after the 2009 earthquake the mitigation scenario of building houses resistant to earthquake was studied. The results can be summarized as follows:

- Benefit of using the LUPM to support decision making: score 8.57/10
- 85% of respondents identify a direct application of the LUPM in their work
- 67% of respondents declared to be willing to be personally involved in future research with the LUPM.

The participant reaction was encouraging and the benefits recognised included mitigation advocacy, prioritization of activities and support enforcement of policy, while the main challenges identified comprised confusion around complex themes, risk perception focused on tsunami, and the difficulty to involve community/religious leaders.

3.6 Geoinformation Transaction Costs: Why Do They Matter? (A. Poplin)

An exchange of spatial data is a transaction that involves parties, e.g. the seller and the buyer who have to exchange information about the geoinformation product (data or service). A transaction can be costly: it is an investment both in time and in effort, and in money at the end. With respect to classical goods, spatial data have the peculiar characteristics of an experiential good, meaning that the user/buyer is able to estimate the fitness of use of the dataset for an application after testing it.

Assumptions of the neoclassical economic theory include the perfect information and the consideration of users as rational agents, and the perfectly secured property rights. The costs of transactions have been introduced by Nobel prize Coase (Coase, 1937), according to whom, when it is costly to transact, institutions have a role. Coase has contributed to the New Institutional Economics, together with Williamson and North (Williamson, 1985, Williamson and Masten, 1995). According to North (1990), the costliness of information is the key to the costs of transacting. The costs of transacting consist of the costs of

- measuring the valuable attributes of what is being exchanged (MEASUREMENT costs) and
- the costs of protecting rights and policing and enforcing agreements (ENFORCEMENT costs).

These measurement and enforcement costs are the sources of social, political, and economic institutions. Starting from this background, Hafencity University of Hamburg has carried out a case study based on the simulation of the behaviour of a geoinformation user. These experiments were undertaken by urban planning students. They were not geoinformation experts, therefore they had no particular pre-knowledge of the geoinformation market. They represented, though, a young generation able to comprehend the new possibilities of electronic markets rather quickly. The case study consisted in finding the geoinformation/data, searching for the layouts of the university buildings in the urban areas of Berlin, Vienna and Zurich. The methodology for quantifying Geoinformation Transaction Costs (GTC) is shown in Figure 7 (Poplin, 2010).

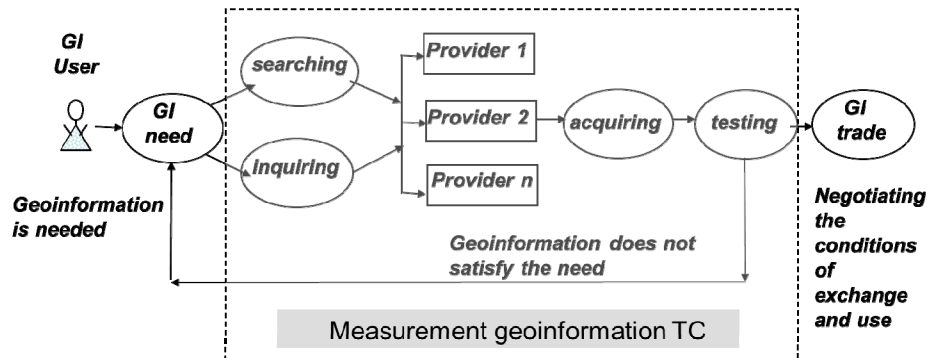
A GeoInformation user, in need of geoinformation, has first to search for the data needed and perform the necessary inquiries to providers, prior to acquire the desired information, which by the way should be tested, and only after that the GeoInformation trade may take place. In this process, Geoinformation Demand Transaction Costs (GDTC) appear on the buyer's side and include the costs related to the data acquisition, while Geoinformation Supply TC (GSTC) appear on the provider's side and include the cost related to: explaining the complex rules about the use of data, copyright issues, non-transparent pricing, non-transparent licensing conditions, rules of sale imposed to the buyers by national mapping agencies or other organisations, providing an access to spatial data infrastructures. The case study could only quantify tangible TC, but there are also intangible TCs to be taken into account (e.g. level of frustration, waiting time).

The Total Geoinformation Transaction Cost (TGTC) is therefore the sum of the Demand Geospatial TCs (DGTC) and Supply Geospatial TCs (SGTC):

$$TGTC = DGTC(t, i) + SGTC(t, i) \quad (t=\text{tangible}; i=\text{intangible})$$

The value of geoinformation derives from the ability to reduce the geoinformation transaction costs, both for the users and the suppliers. Where transaction costs are very high, many kinds of transactions may not take place at all.

Figure 7 Methodology to Measure Geoinformation Transaction Costs.



The following key challenges related to the geoinformation transaction costs, have been identified:

- A variety methodologies for quantifying transaction costs exist, but we lack an overview and an estimation of applicability for geoinformation (products/users/institutions);
- A close collaboration with geoinformation providers is needed in order to be able to quantify the supply geoinformation TC;
- Sometimes the users and the use of geoinformation are not clearly defined;
- The identification and quantification of intangible geoinformation transaction costs;
- The role of languages in geoinformation acquisition, especially in Europe;
- Understanding the characteristics of transactions, in terms of uncertainty, asset specificity (refers to the specialization to a transaction of assets that were invested in to support it), and frequency;
- Understanding the role of institutions/organisations.

Key elements of the program may include: a Value Laboratory/Test Bed in which users may check the value of the geoinformation, the testing of methodologies on several cases and using different methodologies for the same study case, a collection of methodologies for quantifying the value of geoinformation and study cases, setting up a GeoValue Community through a sort of social networks.

3.7 EO Benefits are Obvious, but How Do We Measure Them? (A. Bregt)

This contribution presents the perspective of the author, in terms of experience with Spatial Data Infrastructure (SDI) Assessment, along with personal lessons learned. It then provides an identification of key challenges related to the value of spatial information and a proposal for the programme of activities.

The experience in methodological development has been realised through several PhD research mentoring, in the fields of assessment of SDI clearinghouse, spatial data sharing, multiview framework SDI assessment, assessment of collaboration, role of budget in SDI, role of geoinformation in Environmental Impact Assessment, information and marine assessment.

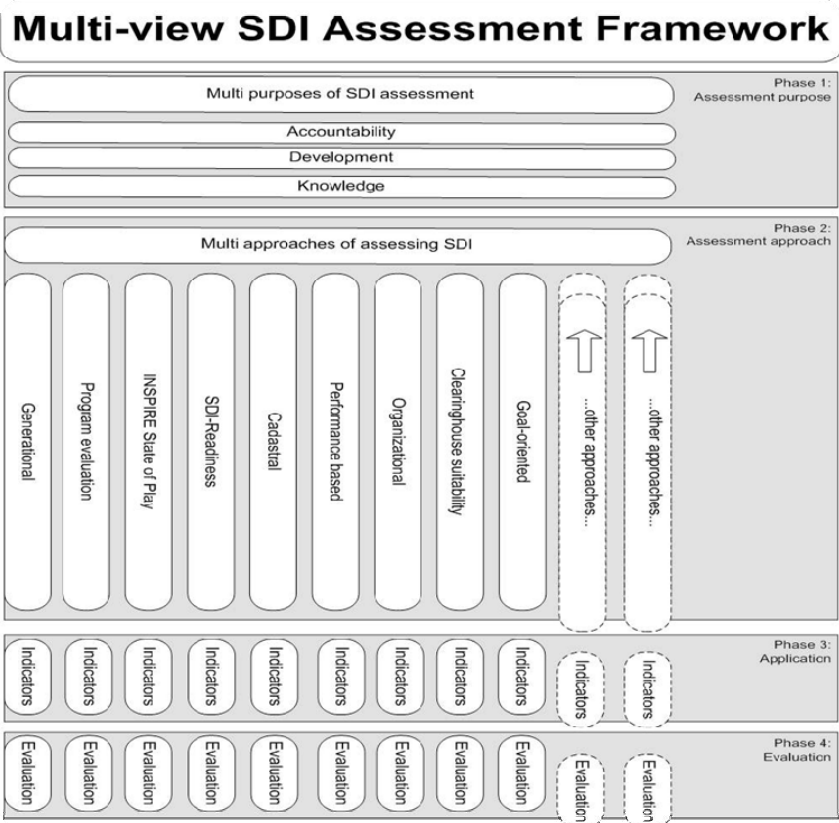
The experience in applications has been achieved instead through personal work on INSPIRE, and on impact assessment of “space for geoinformation”, a Dutch program ran in 2004-2009 with the mission: “Enhancement and innovation of the geo-information infrastructure and the geo-knowledge community in the Netherlands towards sound and efficient public administration and a robust business”. Innovation and collaboration among

geo-research community, geo-data producers, geo-companies and geo-users were the key elements of the program (Bregt and Meerkerk, 2007).

Further experience was gained with the assessment of authentic registrations⁸ in The Netherlands, and the assessment of the status of the Dutch GI sector (Castelein et al., 2010). This study shows that the Dutch geo-information sector is fast developing, and estimates its value at € 1.4 billion, 0.25% of the national GDP.

Lessons learnt from these different experiences are multifold. Firstly, geo data have diffuse impact and benefits that appear unexpected. Secondly, benefit assessment is essential because of the need of justifying the investments of governmental subsidy. This explains why politicians are more interested in ex ante assessment, and not in ex-post analyses. Finally, SDIs as an object of study are complex and not assessable in a simple way.

Figure 8 Multiview SDI Assessment Framework (Grus et al., 2010).



We can distinguish two different scientific schools with different approaches to reality: the Reductionism, for which the reality is made of various components (Cartesian approach) and the Holism, approaching the reality as a system (Aristotelic approach).

It can be demonstrated that SDIs can be seen as Complex Adaptive Systems (CAS, Grus et al., 2010), characterised by complexity, components, self-organization, openness, unpredictability, nonlinearity and adaptability, scale-independence, existence of feedback loop mechanism and sensitivity to initial conditions. As a result, they cannot be assessed in a simple way.

⁸ Authentic registrations are registrations with a uniquely defined core dataset, which government agencies are obliged to use.

Grus et al. (2010) have proposed a multiview SDI assessment framework to capture those peculiarities (see **Figure 8**). This framework was applied to the SDIs in 20 countries in the world.

Key challenges identified for future activities require the shift from ex-ante to ex-post SDI impact assessment, from anecdotes to integral assessments, from datasets to constellation of datasets, from benefits to decision makers to benefits to society.

To achieve these goals, smart indicators are needed, as well as an extensive ex-post evaluation of Landsat programme, the concept of a life cycle analysis of data (integral over years). It could be also useful thinking about drawbacks of EO, not only about benefits, and analyse the role of spatial data in spatial thinking.

3.8 Assessing Information Infrastructures from the Business Perspective (D. Vandenbroucke)

The Spatialist initiative (2007-2011) was funded by the Institute for the Promotion of Innovation by Science and Technology in Flanders (IWT) with the goal to advance research on SDIs for public Sector Innovation. The research team includes researchers from public administration, geomatics, law, sociology, economics.

Central research questions are about the technological, legal, economic, sociological and public administrative requirements to further develop an operational Flemish Spatial Data Infrastructure consistent with international standards that is efficient, effective, flexible and feasible.

Different organisations dealing with data are interconnected, but still there are barriers to the access of data. The study mapped the behaviour of 500 different organisations at different scales in the Flemish region, looking at them from the “network perspective”, by means of surveys repeated in 2008 and 2011 with 250 responses, analysed with Actor/Network Theory and Social Network Analysis (see Vandenbroucke et al., 2009).

Researchers recognised that the holistic vision is not enough and that a zoom to the business processes vision is needed (see in Figure 9 an example from flood risk maps and management plans), in which the decision step are clearly explained to all the actors.

The organisation of actors involved in the decision-making and the different perspectives have an impact on the performances of SDI. It would be interesting to analyse what SDI is contributing in this decision-making process, in terms of access, use and sharing, of efficiency and quality, flexibility and innovation, transparency and reliability.

Based on these considerations, key challenges from the project perspective regard the performance measurement, because impact on society at large is missing and outcomes are expected in the long term. Existing attempts to find indicators to measure impact towards the citizen and SMEs proved to be difficult.

The interesting question is for example: are there fewer floods because of the use of geospatial information?”

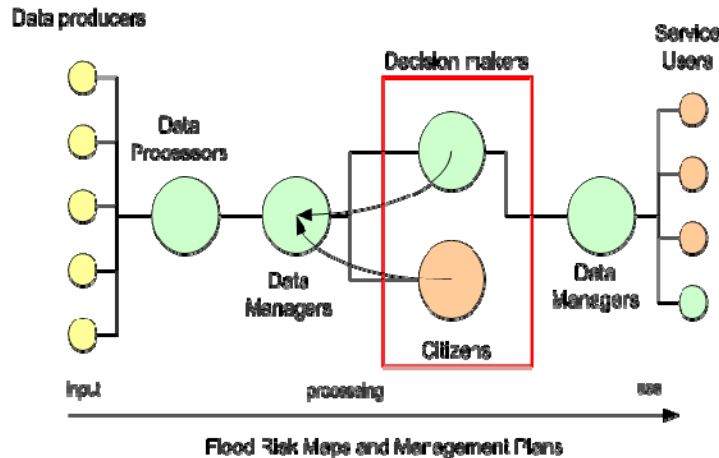
In addition, the problem of attribution is also worth dealing with: it is not clear indeed if the decision-making process is getting better because of the SDI or not, and which factors really make the difference. SDI should serve many users, so maybe it is good for one, but not relevant for others.

Finally, SDI assessment should be integrated in performance management, making the link to Business Process Management (BPM) and should not be done only from the technological point of view.

From the broader perspective, we don't know much about the user and the usability perspective of the infrastructure; the trend is not only to assess the infrastructure per se, but

also what and how we do things and take occasions for streamlining data processes (see Shared Environmental Information system, SEIS). Certainly we do not need only one overall framework to assess SDIs, but rather to integrate methods at different levels, define clear goals and what do we want to measure.

Figure 9 **Example of a Business Process Model.**



From the perspective of the project, a concrete proposal would be to measure the impact of the application of geo-standards in work processes (or any other component), similar to what has been done in Booz Allen Hamilton (2005). It would be interesting to focus on the impact of semantic standards and on the development and application of data specifications, taking into account the costs of standardisation (data specifications development, implementation). A useful case study would be to see the different impacts from applying or not the standards, linking this to the specific processes and have a measurement system at that level. Also the interoperability, the efficiency of the flows or vice versa the impedances should be measured, as well as the impact on the policy concerned and the impact at large, on society.

From the broad perspective, analysis of real use cases would be desirable. Because real work processes reflect a decision making process, the use case should be fairly complex and include many types of users, possibly showing and testing scenarios “with” and “without” the use of SDI & GEOSS components. Moreover, the research should focus not only on the data per se, but how they are made available – including the technological and organisational environment.

A quantitative and qualitative measurement framework should be developed, describing processes, analysing the impact of different components / ways of working. The concept of “plugfests” could be explored, not (only) with experts, but mainly with end users involved (including some “dummies”).

The result of this testing phase on a so-defined case study would result in a “piece of theatre” or a “film” showing the scenarios. Finally, it is proposed to define a framework to measure geomaturity of society.

3.9 What Impact of Spatial Data Infrastructures on Innovation? (*M. Craglia*)

The new priorities of EU reflect less concern about environment and more about social development: infrastructures and research are seen as means to create jobs and innovation. For this reason, the European Union has directed the 2020 strategy towards sustainable growth.

JRC has studied the impact assessment of SDIs through the Extended Impact Assessment of INSPIRE (Dufourmont, 2004) and some studies on regional SDIs (Craglia and Nowak,

2006, Craglia and Campagna, 2010). These experiences have highlighted that most investment costs identified in INSPIRE are an order of magnitude higher if analysed at the subnational level, and they are necessary at the local/regional level to build capacity, technical and organisational expertise, and generate change in the public administration. On the other hand, we *assume* that SDIs and increased access to PSI will lead to economic development, but again there is no hard evidence to date, particularly at local/regional level.

Within the literature about regional economics, the work of Porter (2003) has been crucial to recognise that many of the essential determinants of the economic performance of a nation reside at the regional level, and that institutions play a significant role in promoting innovation in regions. According to Porter, one of the main drivers of regional innovation is the organisation of firms in clusters. Clusters are geographic concentrations of related industries linked by externalities such as pooled labour, and knowledge spillovers, and represent main mechanisms for fostering growth, innovation and competitiveness, particularly among SMEs. For this reason, industrial clustering was adopted as a strategy at the national level in many countries (see examples of regions like Silicon Valley, Baden Wurttemberg and North-East Italy).

Recent literature has confirmed these assumptions related to “traditional” types of firms, talking about cooperation and networking as drivers for innovation, introducing the concept of “virtual” clustering (Mention, 2011).

Malmberg and Maskell (2002) argue that “A key argument within economic geography is that the increasing importance of knowledge-creating processes for competitive advantage in a global economy is reinforcing the tendency towards urban and regional clustering”.

“Spatial proximity between specialist firms facilitates the creation and exchange of tacit knowledge, viewed as a crucial form of competitive advantage in a world in which codified knowledge is easily replicated and rendered ubiquitous” (Cumbers and McKinnon, 2004).

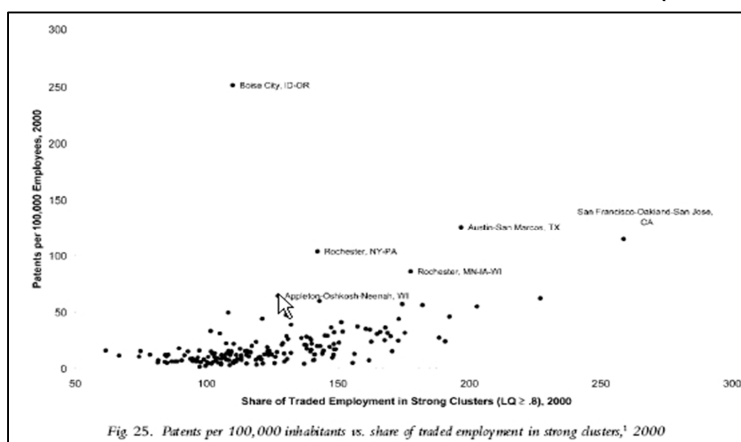
In the age of globalisation, clusters and regions may become critical factors of success deriving from their peculiarities (Craglia and Johnston, 2004). Therefore, it may make sense to think about a program of research that could deliver similar outcomes than in Porter (2003). There, it was found that there is a correlation between innovation (represented by the proxy “number of patents”) and strong clusters (Figure 10).

In particular, as many regions are investing in SDIs, it could make sense to ask the research question whether they would gain competitive advantage from it, e.g., if SDIs may have an impact on innovation of regions.

The problem is not trivial from the socio-economic perspective. The current Standard Industrial Classification fails to deliver meaningful statistics about the Internet and the digital sector, because it is embedded in the “publishing sector”, thus hidden behind the effects of media such as TV, newspapers, books and cinema, therefore it is difficult to know the effect of the digital era on occupation and social growth. At the same time, statistical institutions (e.g. Eurostat) need to include information about the digital sector in their statistics, but lack of a supporting framework and of methodologies to build a set of consistent statistical indicators.

Based on these considerations, several research issues may be put on the agenda and become material for a proposal of activities. For example, to what extent data and information flows available through Regional Spatial Data Infrastructures produce innovation (and related employment and growth) for public and private sector in European regions? Are clusters relevant to the e-economy? How do we define the e-economy? How to measure innovation? What is the nature of the emerging value chains in the e-economy? What is their geographical footprint? Does clustering occur and does it matter? What are the levers available to (regional) governments to facilitate innovation and competitiveness of their economy in the e-society? What is the risk of investing locally for benefits elsewhere?

Figure 10 Correlation between Innovation and Clusters (Porter, 2003).



A useful research project proposal could start from a survey of active firms in GI /EO sector, to gather relevant information on the clusters' dynamics/behaviour.

The output of a similar survey could help the analysis of the impacts, on regional e-economy, of innovation/growth achieved in firms thanks to regional SDIs, that make use of EO data.

3.10 The Value of Information: Applications in the Field of Land-Use (S. Fuss)

In this contribution, EO benefit estimation is considered as a valuation problem, because benefits vary with users, context and time, and these are getting more and more interrelated. The time is entailed in considerations regarding dynamic valuation and updating, while the context is related to the choice between monetary valuation and value free indicators, and the identification of options and their interrelations.

The difficulties with ex-ante benefit assessment are related to the possible biases in ex ante cost estimates, the lack of information on events with low probability, but potentially high impact, the under- or even un – valuation of benefits when unforeseen damage has been avoided.

On the other hand, Value of Information estimation may be carried out with different methods, from different perspectives and iteratively.

This contribution presents a case study in the land-use sector, showing how a standard portfolio optimisation approach may be used to calculate the Value of Information. The aim is to find the optimal composition of the mitigation portfolio, where the decision-maker has two mitigation options at his disposal to reduce 20 Gt of CO₂. The optimisation consists in minimising the weighted sum of expected costs and variance, where the weight of variance represents the level of risk aversion.

The Expected Value of Information is defined as the willingness to pay for information (Birge and Louveaux, 1997), and measured as the value of the objective (here: costs) without information at the time of the decision, minus the expected value of the objective with information.

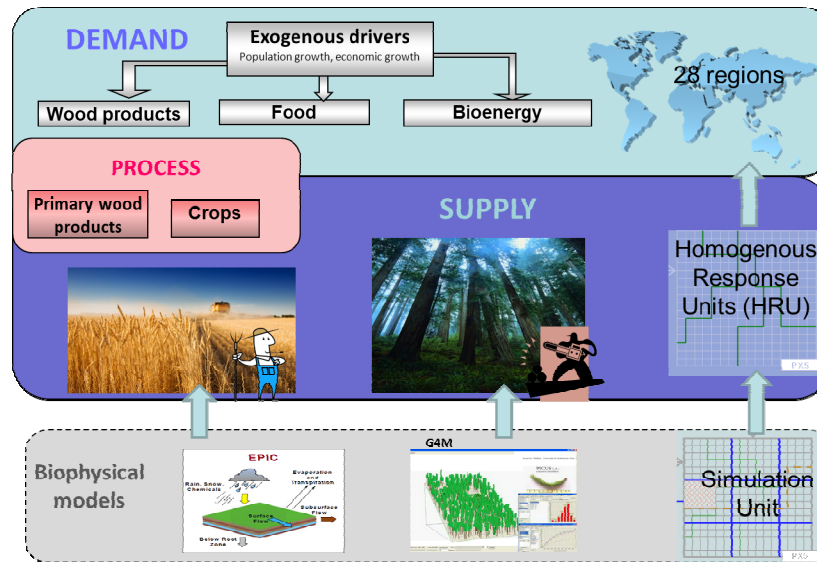
The first mitigation option entails the implementation of a new technology such as carbon capture and storage (CCS) in the industry/energy sector, which is assumed to exhibit constant costs. The second option is named Reduced Emissions from Deforestation and Forest Degradation (REDD); the costs of mitigating CO₂ by avoiding deforestation increase as less and less land is available and because we are not sure whether the land cover map showing more land to be available is closer to reality or the map, which is less optimistic, the decision-maker also faces major uncertainties with respect to the costs of this option (Macauley and Laxminarayan, 2010).

The Global Biosphere Optimization Model (GLOBIOM) is a bottom-up partial spatial equilibrium model, covering 28 regions in its basic resolution, with the objective of

maximising the producer and consumer surplus (Figure 11). It was used to assess the costs of avoiding deforestation for different maps of land cover.

An important conclusion from this application is that, even if the decision-maker is risk-neutral, the existence of uncertainty leads to a portfolio of the two mitigation options and a positive expected value of information rather than a pure strategy using only the option that is on average cheaper. It is therefore true that Value of Information depends on context. In terms of the numbers, it might be just a fraction of the overall mitigation costs, but is very high in absolute terms (Macauley and Laxminarayan, 2010).

Figure 11 Application of the GLOBIOM Model to the Two Selected Scenarios.



On the other hand, as better land cover information can be very valuable, in situ measurements and validation points are needed.

In conclusion, from the users' perspective, it is needed to minimize the costs of the policy portfolio, taking into account different objectives and additional constraints, trying to estimate benefits from different viewpoints with different methods.

Moreover, the fact the VOI depends on context makes us deal with varying targets and costs under different sets of information, and with different options available and their interactions (e.g. complementary vs. competing options).

3.11 Assessing the Value of EO for Environmental Management Based on Bayesian Decision Theory and Expert Elicitation: Challenges and Opportunities (Onno Kuik)

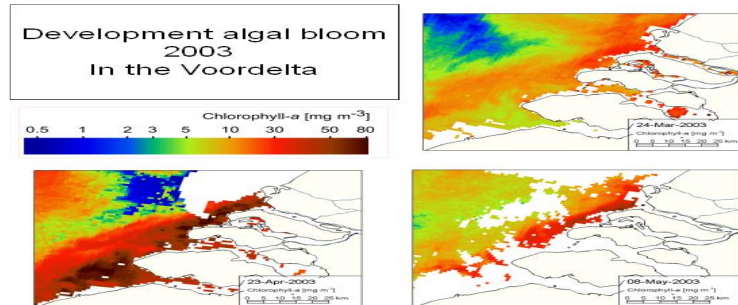
The main objective of the EU funded GEOBENE project (2006-2009) was to assess the benefits of Global Earth Observation (GEO).

Estimating the incremental costs and benefits of GEO information involves several steps:

- 1) a **baseline** has to be established against which the availability of information is compared;
- 2) a set of **potential decisions and actions** needs to be defined. For example, if decision makers would have 'real time' information about forest fires how would this change the decision made;

- 3) the **impact of additional information on decision making** needs to be assessed. Although some approaches simply assume that additional information is being used, stakeholder oriented approaches explicitly account for this factor;
 - 4) the **potential welfare impact** of improved decision making needs to be assessed.
- To illustrate this approach, two case studies have been carried out, on the Dutch water quality management in the North Sea (Figure 12) and on the Great Barrier Reef lagoon.

Figure 12 The North Sea Case Study.



For the North Sea case (Bouma et al., 2009), the baseline was the existing information system consisting of mainly 'in situ' data collection. 25 senior water managers and experts were asked to compare this baseline with a scenario with additional GEO information, concentrating on the example of excessive algal bloom. If decision makers have access to early warning information they can prevent an economic damage of approximately 20 million euros every 5 years. The potential action decision makers can undertake to relocate fishing nets at an expected cost of 2 million euros.

Respondents expected that decision makers would take immediate action if better information was available to prevent damage from excessive algal bloom. They estimated the impact of additional information on decision making to be an improvement in the predictive capacity of the information system of on average 50% (from 75% to 50% uncertainty).

The potential welfare impact in terms of avoided damage costs is estimated to be 1 million euros/year. Accounting for the variance in respondent estimates, the 95% confidence interval ranges from -0.1 to 2.1 million euro/year. Since the costs of additional data processing are low, in most cases benefits exceed costs.

Both case studies suggest a substantial benefit of EO information (North Sea: net annual benefit € 24.000; Great Barrier Reef: gross annual benefit AUD 37 million). Taking all else equal, willingness to pay for EO information is higher if the stakes (pay-offs) are higher, if present uncertainty of decision making is higher, and if reliability of EO information is perceived to be higher. It should be noted that in these studies, the knowledge of environmental managers of the potential benefits of EO was quite limited, and that the decisions/actions of environmental managers may be constrained by law and regulations. One of the main difficulties was to frame the policy problem in such a way that it could be simple enough for the analysis, but also not so simple that it would not do justice to real-world complexities. Finally, it is often difficult to assess the monetary value of the environmental pay-offs.

Recommendations for the programme of activities include:

- a better understanding of the policy problems to which EO information is supposed to be valuable, including constraints to decision making and distribution of responsibilities (policy analysis);

- the set up of laboratory-style experiments to test certain basis assumptions on how people deal with EO information in decision context (experimental economics, social psychology);
- importance of doing ex-post assessments.

Table 1 Pay-off matrix in the North Sea Case Study, with Additional EO Information.

		States	
		s=1: harmful bloom	s=2: no bloom
Acts	a=1: relocate fishing nets	-2	-2
	a=2: do nothing	- 20	0
Beliefs if message = "Danger!"		0.75	0.25 (Type I error)
Belief if message = "No panic"		0.10 (Type II error)	0.90

3.12 Australian Economic Benefit Assessments; Pricing Models and now Socio Benefits (*K. Armstrong*)

In the Australian case, SDI and Spatial Information Programs were not getting a hearing at the political table, for issues related to language, drivers, fragmented and inconsistent approach.

Therefore, a study on the economic benefits of high resolution positioning services was carried out (Allen Consulting Group, 2008). The objective of this study was to estimate the current and future economic benefits (measured in terms of contributions to national GDP) resulting from the uptake of various applications of precision GNSS technology in three key industry sectors — mining, agriculture and civil engineering/construction. Preliminary investigation and modelling was also undertaken for applications of precision GNSS to asset mapping, which is currently being used in the utilities and public works sector.

The economic value of productivity gains from applications of precision GNSS in the agricultural, mining and constructions sectors were modelled using a computable generalised equilibrium model, the Monash Multi-Regional Forecasting (MMRF) model run by the Centre of Policy Studies at Monash University. MMRF is a multi-sectoral, multi-regional dynamic model of the Australian economy. It produced estimates of the 'first round' economic benefits to firms as a result of assumed cost savings and/or higher output levels. It also captured the second round benefits accruing to upstream and downstream industries, which were incorporated into the GDP changes.

MMRF contains a representation of each region as an economy in its own right. Being dynamic, the model is able to produce sequences of annual solutions connected by dynamic relationships.

Based on a scenario whereby a standardised network is rolled out across Australia, the technology is estimated to increase Australia's GDP by between \$6.7 billion and \$12.6 billion in today's dollars by 2030. This equates to a percentage increase in GDP of between 1.1 and 2.1 per cent.

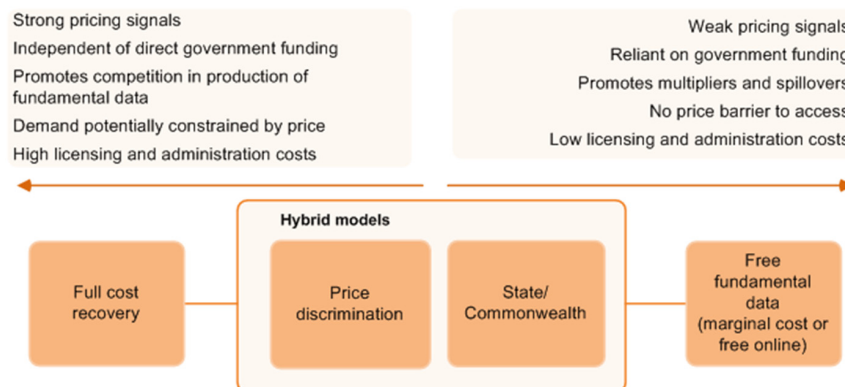
A second experience is the Economic Assessment of Spatial Data Pricing and Access (PriceWaterHouseCoopers, 2010). Starting from the recognition that pricing and access policy was critical for the future sustainability of the spatial data industry, and that there was

not consistent approach to pricing with differing schools of thought with a focus on “fundamental spatial data” (recent calls for public sector data had to be provided for free), the study tried to investigate which was the best policy for long term economic benefit to society, and whether fundamental spatial data is a special case.

The project objectives were to consider a range of economic models and policies for accessing and pricing public sector spatial resources for long-term sustainability, to analyse the costs across the whole value chain and apply dynamic economic analysis (Allen Consulting Group, 2008). It builds on previous economic studies by addressing dynamic effects of pricing on quality and subsequent demand and taking into account the public good characteristics of spatial data, the effect of pricing signals on consumption and production decisions, and competition and innovation aspects.

In particular, fundamental data have natural monopoly characteristics, such as fixed costs making up a large share of total production costs. They are also typically produced by government land information agencies, therefore if a cost recovery approach is adopted, prices must be set to recover fixed and variable costs, and setting prices at marginal cost (the efficient level) results in under recovery of revenue for the agency. However, setting prices at average cost results in a ‘deadweight loss’ if consumers are price-sensitive. One approach is to recover fixed costs from customers with inelastic demand, so as not to distort consumption from efficient levels. Alternative models for analysis are shown in Figure 13.

Figure 13 Alternative Models for Analysis.



The main conclusions of this study are that fundamental spatial data are dynamic in nature and datasets require on-going maintenance to retain their value; all components of the spatial data value chain must be assessed when determining pricing and access policies; when dynamic economic analysis is applied, the initial benefits of increased data use ascribed to the free model are quickly eroded if data quality is not maintained and funded; the move from full cost recovery to price discrimination has most of the benefit of a move to the free fundamental data model if the Government is the greatest user; pricing policy needs to be determined for each dataset, not at an agency or whole of Government level; there is no uniquely optimal access and pricing model when a range of practical and dynamic considerations is taken into account.

Based on these, it is safe to conclude that free pricing policy is the best depending on jurisdiction’s policy objectives and funding, and that fundamental data are indeed a special case, due to high fixed costs and need for on-going maintenance. Therefore, we need to justify our existence and future spend, to create a consistent story, to provide a methodology that can be used across sectors and into the future, to provide the research Community with a point of reference that has credibility in the funding areas, to be clear on the scope and assumptions and to use economists’ expertise to provide economic assessments.

Following the many projects existing to develop indicators around the world and in Australia, in the different areas such as society, economics and environment, our research proposal is (i) to develop a Progress Dashboard, (i.e. a control panel) where indicators can be consistent but taking regional and economic differences into consideration; (ii) to establish an economic research framework that can be used by GEOSS researchers when justifying investments and can leverage the provision of consistent trusted terminology.

3.13 Value of Earth Observations: Forest Fires, Earthquakes, and Landslides (*N. Khabarov*)

One of the aims of the GEOBENE project was the development of a methodology for the assessment of the value of EO and Information. Earthquakes, landslides and wild fires (and related disasters) are among the Societal Benefit Areas (SBAs) looked at by GEOBENE.

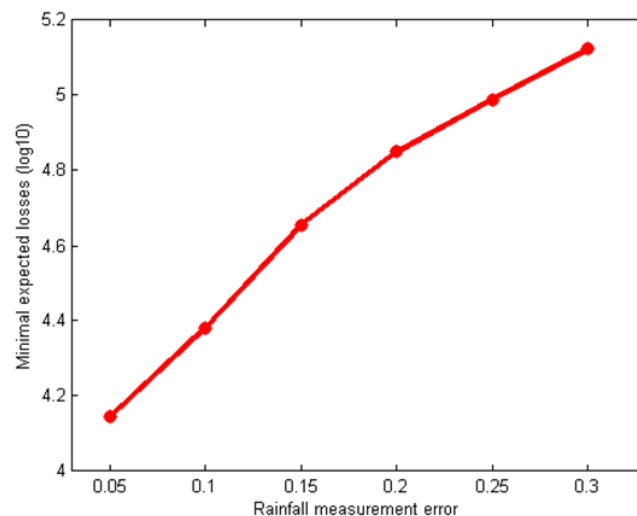
The objective of this study, in particular, is to quantify the incremental value of information, due to improved EO, trying to identify its costs and benefits.

In the case of earthquakes, scientists are able to obtain a rapid damage assessment based on networks of sensors able to match indicators about severity and magnitude. The rescue efficiency may be simply calculated as the ratio between the saved and total victims (Moltchanova et al., 2011).

With limited resources and big earthquakes, the EO data become important. This assessment could be useful because there is the need to distribute health resources where it is more efficient.

In the case of landslides (Huggel et al., 2010), the modelling phase makes use of rainfall data and landslide threshold indicators, adjusted to minimise losses taking into account Rainfall Measurement Errors (RME), to develop evacuation criteria useful to calculate the damage and therefore expected losses. In Figure 14, the expected losses on log10 scale are plotted depending on RME. The losses accounted for are calculated as the sum of evacuation costs and fatalities and represent the ones that an Early Warning System is able to reduce. This is only related to people, building damage is not taken into account.

Figure 14 Expected Losses depending on Rainfall Measurement Error.

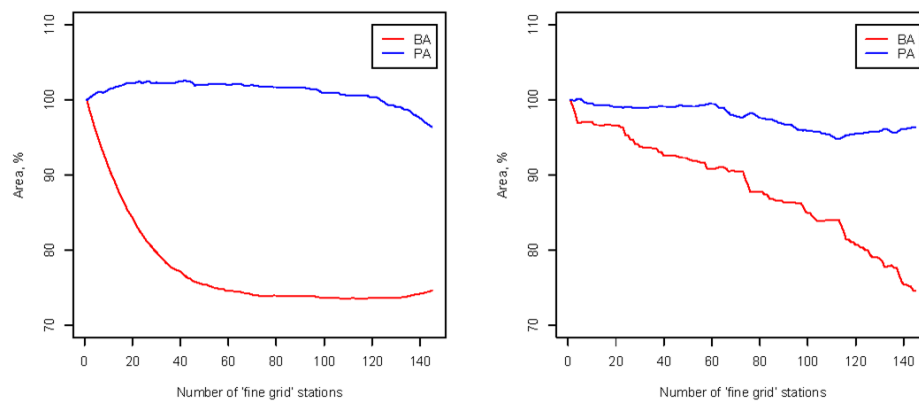


In the case of forest fires (Khabarov et al., 2008), the research area covers the territory of Spain and Portugal, modelled with two grids of different resolution: a “fine” grid of 12x12 cells, 50x50 km, and a “rough” grid, of 6x6 cells, 100x100 km. The aim of the case study was to analyse the impact of a new weather station on the forest burnt area. Combining weather history and fire history, it is possible to calculate the fire probability. Results show that the addition of weather stations supports reduction of burned area. In Figure 15 two charts are

shown. In the left one, priority is given to the reduction of burnt area (BA, in red), while in the right one priority is given to the reduction of patrolled areas (PA, in blue). In both cases, we see a reduction of burnt area, but in the first one, this is more responsive to the addition of more “fine” grid stations at the beginning, while in the second one the diagram is quasi-linear.

From the experience of these case studies, we may conclude that the main challenges in the task of understanding the value of geoinformation are the need of new data to evaluate, because they cannot be simply generated; the need of existing data to develop models, the need of connections to practitioners to validate models. These have to be added to the usually considered challenges, namely complexity, dependence on users, models, benefit generation chains, availability of applicable methodologies.

Figure 15 **Burnt Areas and Patrolled Areas Reduction due to Increase of “Fine grid” Stations.**



Based on these considerations, key suggestions would be the identification of an expert panel to define pilot projects for new data acquisition and Vol estimation, as an investment measure. As incentives measures, the promotion of sharing existing data for scientific purposes and a platform linking modellers and practitioners for results validation might be envisaged.

3.14 Accounting for People in Earth Observation - Some Experiences from Italy (A. Giacomelli)

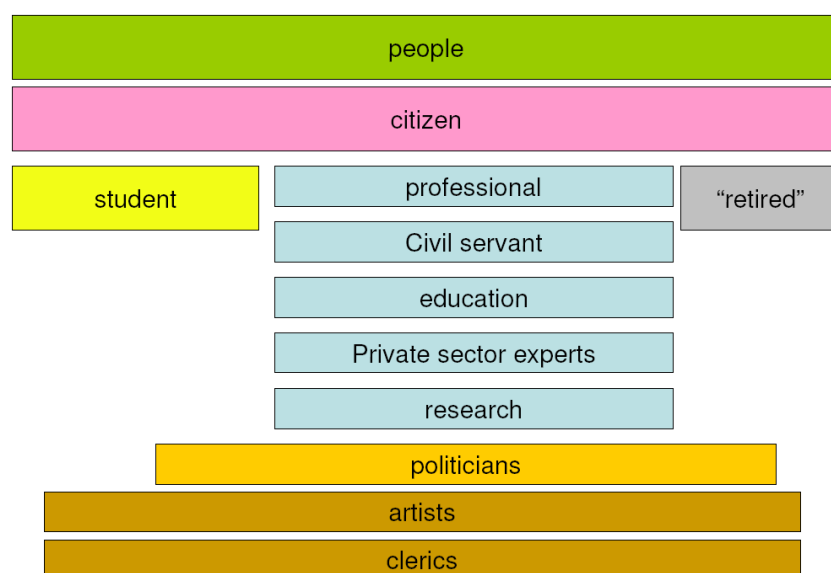
This presentation defines the perspective of the author by means of the description of his previous work, particularly concerning the role of users in the development of valuable Geographical Information.

Main activities since early 2000s have included Voluntary Geographical Information and communication activities such as participatory dark sky quality monitoring, and other initiatives (in Italy but not only) to align private sector SDIs to public sector SDI and to promote integration among different fields such as environment and informatics. The author is also participating to the INSPIRE data specification process.

The author is in particular interested in classifying people according to their roles (see Figure 16) within a given project or program, as this allows an assessment of the social context in which the project or program should take place. On the basis of his experience, the author presents the challenges that should be addressed in a possible programme of activities.

The first idea is that it is difficult to agree upon a value if we do not share values: so there is the need to understand what is important now, in this moment, for the people as stakeholders.

Figure 16 **Classification of the Roles of People according to Giacomelli.**



Internet does not make such an assessment simpler, because there is the need to overcome language/lexicon/cultural issues, that are not global indeed.

On the other hand, values apply not only to ends (data and information), but also to the means, namely to the methods.

Other types of challenges to be overcome are the need to differentiate between administrative boundaries and boundaries of purpose; to consider the existing data/tools/people/process imbalance and the overloads of data/tools/processes, as well as the different views of the same pictures.

A proposal is to consider each of ourselves as a user, and to ask ourselves what are socioeconomic benefits of EO to us. Having clarified this, it is possible to shift to a wider community, taking a defined time to define a concerted answer, and then share the outcomes with the rest of the world.

A final recommendation involves the re-modulation of investments on new topics reallocating budgets to first consolidate and exploit existing results which seem to be currently unexploited. Efforts should be dedicated to “history” (such as improving access and knowledge of existing bodies of literature on the world). Rewards for interdisciplinary work are also proposed as a way to progress on the evaluation of socio-economic benefits of EO.

3.15 Building a Network to Model World Food Security: The Agricultural Model Intercomparison and Improvement Project (AgMIP) (A. Ruane)

World food prices respond to many factors: they show higher volatility and commodity-dependence. In particular, they are affected by the effects of climate change. There is therefore the need to understand the more and more frequent weather extremes. Examples are the 2010 extreme heat wave, resulting in drought in Russia, the central US floods in May 2011, the Back-to-back 100-year floods in the Northern Great Plains (US) during 2009 and 2010, the recent floods in Australia following destructive wildfires, the 2010 failure of the Ukrainian grain crop due to heat wave, and the devastating drought in Niger during summer of 2010.

Serious weather extremes affect food production and therefore intensify humanitarian problems: as an example, over the past years the eastern Horn of Africa has experienced two consecutive poor rainy seasons, resulting in one of the driest years since 1950/51 in many pastoral zones. The impacts of the drought have been exacerbated by high local

cereal prices, excess livestock mortality, conflict and restricted humanitarian access in some areas.

The elements and linkages of the AgMIP project (Agricultural Model Intercomparison and Improvement Project) are shown in Figure 17. The main core consists in the understanding climate scenarios to feed crop models and therefore agricultural economics models, making use of information technologies, and having as outcomes intercomparisons amongst models and methods and capacity building. Cross cutting themes of the projects are (i) uncertainty, as each component has a contribution to the uncertainty cascade; (ii) aggregation across scales, to connect local, regional and global information; and (iii) representative agricultural pathways, linking to RCPs (Representative Concentration Pathways of Greenhouse Gases) and economic pathways as well.

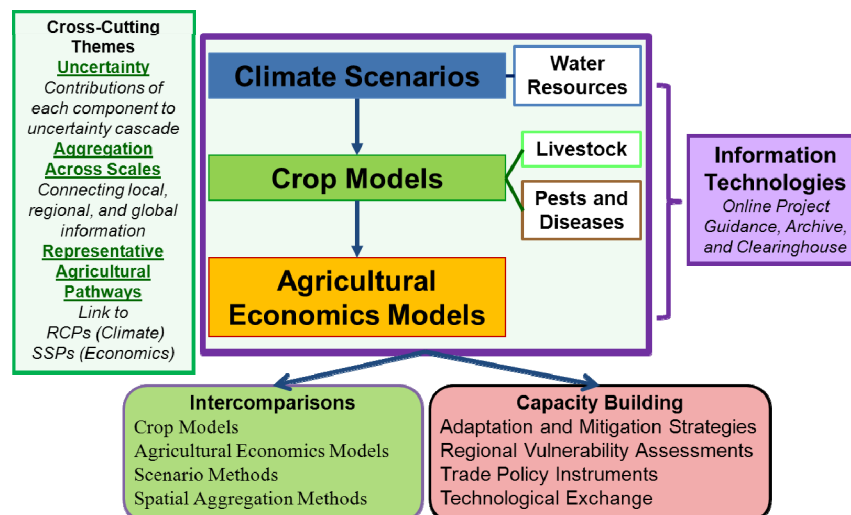
The project considers a two-track science approach: the first one aims at modelling intercomparison and improvement; while the second one aims at developing coordinated future scenario simulations.

In particular, the AgMIP initiatives are crop-specific and focus at a regional scale.

From the socioeconomic point of view, the benefits of AgMIP consist in:

- Improving scientific and adaptive capacity of major agricultural regions in developing and developed world
- Developing a framework to identify and prioritize adaptation strategies
- Including multiple models, scenarios, locations, crops and participants to explore uncertainty and the impact of methodological choices
- Linking to key on-going efforts

Figure 17 Elements and Linkages of the AGMIP Project



As regards the use of EO in support of agricultural impacts assessment, the key challenges to valuation consist in dealing with a transdisciplinary cascade of input and outputs, an unknown network of users with varying capacities, the ethical aspects of information availability, and the identification of key sources of uncertainty to prioritize data collection.

3.16 Benefits of Earth Observation: a Brazilian Perspective (H. Ferreira)

INPE, the Brazilian National Institute for Space Research, is the main civilian organization for space activities in Brazil. With 2500 people employed and many facilities in the whole country. In 2011 it achieved 50 years of activities in the field of EO. Its mission is to carry out

research and development in space, atmospheric and environmental sciences, and provide unique products and services for the benefit of Brazil. INPE activities are based on the assumption that EO data are essential for the planet.

The data Receiving Station is located in Cuiabá (MT), a privileged position in the centre of South America, making possible to track Brazil and neighbouring countries. The Alcântara Launch Center (CLA), in Maranhão, has also a privileged geographic location, close to the ocean and to the Equator. It is favourable (in terms of price: saving 30% of the fuel) for launching low equatorial orbit rockets and satellites. The Barreira do Inferno Launch Center (CLBI), in Natal, was built in 1965 for launching meteorological sounding rockets and small size rockets. In Cachoeira Paulista, the Center for Weather Forecast and Climatic Studies (CPTEC) and the Images Generation Division (DGI) are based. The centre of Remote Sensing activities is located in Cuiabá Ground Station Remote Sensing Data Centre, that has been operating for more than 35 years. Brazil was the third country in the world that started using LANDSAT images. Recently, in a joint effort with China the CBERS Chinese Brazilian Satellite has been launched.

INPE's main activities include remote sensing research and applications, GIS technology research and applications, in particular in the Amazon Regional Center (INPE Amazonia). At this location, research and scientific development is carried out, to become the world reference centre in the monitoring of tropical forests, focusing on Capacity Building. It includes a graduate program in Remote Sensing and Geoinformation (PhD and MSc), for about 100 students; short-term courses in Advanced Geoinformation (SPRING), deploying both face to face and e-learning; international courses in RS and GIS.

At INPE, Amazonia Capacity Building is achieved using TerraAmazon, a monitoring system to map deforestation areas and calculate the annual deforestation rates in the Brazilian Amazon. The UN-REDD Programme and INPE are collaborating to help interested REDD+ countries to set up their own national satellite forest monitoring systems

Regarding the data policy, Brazil used to charge users for each CBERS-1 image requested. The user had to browse the images in a catalogue, choose those images he was interested in, fill in a request form, pay for the request and finally receive the images requested. The number of CBERS-1 (1999) images sold was very low – less than 1,000 images/year. Even changes in price were ineffective to increase sales. For CBERS-2 (2003) the policy changed to open and free access to the catalogue and to the full resolution images. A new catalogue and browse system was implemented. Online registration was possible: any user can browse the catalogue, choose as many images as he wants, and download them for immediate use, without any additional bureaucracy and working on a simple and fast catalogue system.

The distribution of CBERS data jumped to an astonishing 10,000 images/month: in the first year, more than 10,000 new users registered. Today, in Brazil, all the organizations linked to remote sensing, environment, agriculture etc. are CBERS users. The same policy was adopted for CBERS-2B (2007) and will be adopted for CBERS-3 when it will be launched.

More than 600,000 CBERS-2 and 2B images have already been distributed to over 35,000 users in more than 5,000 organizations.

The same data policy has now been extended to neighbouring countries under the footprint of the Cuiaba-Brazil ground station and for data acquired by CBERS around the world and made available through the INPE's catalogue.

Two surveys have been conducted in order to measure the benefits of the policy of free access to CBERS data in Brazil.

The impact on education and research was high: thanks to the access to remote sensing data, more than 15% of papers presented in the last two Brazilian Remote Sensing Symposia used CBERS-2. More than 98% of the users agreed with the policy of open data access. The interested reader may find more details at <http://www.dgi.inpe.br/pesquisa2009/Ingles/index.html>.

Recognised benefits included increased number of projects, new small business, easy access to historical and current data, easy to make demonstration and proof-of-concept projects, etc.).

For CBERS users, CBERS brought the freedom to have data immediately available when you need it, while for private companies the availability of free remote sensing data enables new business development, facilitates trial uses for new clients, makes easier planning new applications, creates jobs by reducing cost of data, increases quality by adding data previously unavailable.

As future activities, CBERS satellites will provide information about global land change on the tropics.

Following this success, we may consider that open access data policies will enable the GEOSS succeed.

Possible case study using Landsat/CBERS imagery may include users, uses and effects of no-cost policy, or the development of a geospatial decision framework.

4 DISCUSSION TOPICS

Participants in the workshop discussed on a variety of topics that may be classified as follows:

1. Main conceptual issues related to the estimation of impacts of EO
2. Creation of a body of knowledge about the field
3. Definition of methods for the estimation of EO benefits
4. Identification of suitable case studies to show the benefits of EO
5. Outreach, dissemination, community building

In the following subsections, the main considerations about each of these topics will be described and deepened, based on the discussion of the presentations and on the outcomes of the working groups set up the last day of the workshop.

4.1 Main conceptual issues related to the estimation of benefits of Earth Observation

Most of the discussion was of course steered towards the identification of the *value of EO data*. Data may have value because of their “attributes” (i. e., the scale, the resolution, the frequency). Alternatively, researchers might be interested in knowing the value of the data themselves, regardless of their attributes (as defined above). In many cases, EO might gain value because they are processed in order to give a more complex information. Ethical aspects of information availability should be an increasing field of research together with the recognition that not all information has value and in some cases information may even hold negative values. The great challenge is to identify this value when it is present and has a high impact on society.

The debate on the value of EO, developed in the series of workshops and research studies described in the introduction to this document, is at its initial stage.

Data, in general, are not classical exchange goods, but they have peculiar characteristics of being replicable and reusable, they may have a long life cycle in some cases. Particularly for EO, Harris and Miller (in press) provide an interesting discussion about the suitability of defining Earth Observations as “public goods” without really thinking at the implications that this term includes from an economic perspective.

According to them, public goods should be non-rivalrous (the consumption of the good by one user does not hinder another person to use it) and non-excludable (It should not be possible to regulate or limit the access to the good). They argue, with some examples, that this is not always the case when dealing with Earth Observations, especially because their access and use may be regulated or limited, and that EO should be better defined as “merit-goods”, showing indeed low-rivalry and low-excludability characteristics, but “explicit recognition of positive externalities” (the impact on society, for example).

This may be linked to the discussion about transaction costs arisen during the workshop. It was pointed out that even those data defined as “free” are not free in fact, because users have often to face the transaction cost of obtaining them, and then dealing with the quality issue and manipulate data to improve them for their needs.

There was broad agreement that a *multidisciplinary approach* should be taken when dealing with EO benefit estimation, engaging not only Earth scientists and economists, but also experts from other natural, physical and social science disciplines. The synergy of disciplines would allow for the choice of the most suitable assessment methodology.

The experts recognised the need to support their research *with strong economic basis*, as not all of them are familiar with economic models and methods. Apart the collaboration envisaged by the multidisciplinary approach, it was recognised the need to “outsource” in some cases the research work to be done from the economic side. This could lead to build an “Economic Research Framework”, to be used by GEOSS researchers when justifying the use of EO systems deployment.

Many experts ascribed the difficulties of building a Vol research community to the *lack of funding*. The consequence of that is the lack of jobs in this area, lack of journals, lack of community, lack of methodologies that can be used, lack of studies. Overcome these difficulties should and find ways to promote their research should be therefore one of the main objectives of EO community, trying to exploit the large investments that are indeed planned to collect and process EO (both remotely sensed and in-situ).

Although the workshop was intended to focus on benefits of EO, it was overall recognised that it is important to understand the costs of data as well, both in terms of fixed and variable costs and of transaction costs. The latter were recognised of particular importance and linked to the special features of data as a different type of exchange good

The importance of identifying the impacts (both costs and benefits) of EO is related to the necessity of justifying existing and future investments both for remote sensing and for in-situ EO. For this reason, decision makers often request *ex-ante impact assessments* of future investments, in order to take advantage of science-based elements to make their decision. Most of the times, however, this is not followed by the adequate monitoring of the investment undertaken; therefore it is not possible to control the goodness of the ex-ante assessment. Hence, there is the need of *ex-post assessments* of EO investments. Although the value of EO investments may be difficult to measure as discussed in this workshop, there is also a sense that in some cases there is no political interest to assess past investments, that are already done and do not influence future political situation.

The capability to *communicate* which are the benefits stemming from the use of Earth Observation may facilitate the uptake of the scientific results in the strategic policies by decision-makers, resulting in science-based investments in the public sector and recognition of the body of research.

Even though policymakers are most of the times the subjects requiring and funding EO cost/benefit assessment, most of the times:

- scientific and policy languages and scopes are different;
- scientific proposals do not link with the policy makers’ business strategy, i.e. they are based on different perspectives.

To overcome these problems, scientists should consider current policy needs, how these needs might be met coming with concrete proposals, knowing which is the level of decision-making impacted.

The decisions taken by policymakers are the result of a complex process that it is difficult to ascribe only to this or that information or to other factors. Hence, there is the need to understand the causality (if any) between “better information” and “better decision”, provided that the improvement of a decision thanks to the use of specific information is measurable. In other words, it is not clear which are the factors of the information (and of the underpinning SDIs) that make a difference and have influence on decisions. This activity would imply the integration of different disciplines, and could represent one of the objective of the program of activities, linked to the multidisciplinary issue.

The issue of the language/jargon arises also when the benefits are communicated to not-expert people, in order to explain what EO may bring to them. Moreover, the language issue can be recognised also when dealing with the market of information: users have to disentangle themselves from the intricate network of terminology, providers, data, license, pricing issues before having data they need at hand, facing transaction costs.

Different options are suggested to overcome this discrepancy between scientists, policy makers and rest of users:

1. Train scientists to improve their communication skills;
2. Look for boundary organisations, who can act a links between different communities;
3. Hire communications experts.

It was recognised that it should be made clear that the impacts of EO should be sought in the very little changes that may achieve greater benefits if they scales up for huge numbers of users, and that policy-makers needs should be anticipated, by explaining EO impacts before their request.

For the reasons outlined above (i.e. small benefits may become greater when multiplied with large number of users), the assessment of the impacts of EO should consider carefully the wide range of different users of information, and increasingly, the blurring between data producers and users, as is the case of citizens providing Volunteered Geographic Information (Goodchild, 2007).

Users should be identified and considered in their diversity of interpretation and approaches, to understand the corresponding variety of values that can be ascribed to EO data. People are the ones who use EO data, but the scope and the modality of such use depends very much on the role they have inside the society, the context of that use and the time when data are used. These factors are not isolated, but they are mutually interrelated. Therefore, the first challenge is to find a suitable classification of the users of EO, in order to make data more appealing to them, depending on their needs. The main problem is that the broad network of users of EO data is unknown, as users of publicly available EO data are often not identifiable.

Users should be also better informed about the value of EO information. This could imply the need of training and education of people in the field, in order to make them better understand the value of data underpinning their work and hence, the value of their work. With the global crisis looming large and the need to overcome the current employment challenge, increasing demands for innovative solutions climb the political agenda of many countries and the huge investments made in the field of EO should contribute to meet the job creation challenge.

EO benefits are traditionally identified in the form of time and financial savings, more informed decisions (however measured), direct job replacement or displacement from new technologies. Now there is the need to look harder at *the innovation potential of wider data access* in the forms of innovative products, companies, business models and so on. Innovation is often an elusive concept to define and measure, but it would be possible to draw on the literature on innovations and industrial clusters to assess their applicability to the digital economy.

From this discussion, the idea of clusters (see section 3.9) as key drivers for innovation was identified as worth of a multidisciplinary study, as clusters facilitate mobility of employees and ideas, even if the dynamics brought about by virtual clusters should be taken into account.

Public Sector Administrations are particularly interested in knowing the benefits of EO, as they are in particular those putting in place investments for the benefit of the society (see introduction). As described in section 3.4 (Longhorn), a case study on public bodies interested in coastal and marine data, showed that public administrations might substantially benefit from the reduction of uncertainty in data and information used to make decisions.

Along the same lines, a particular area to explore is the assessment of the benefits and costs of the Spatial Data Infrastructures which make it possible to share more effectively information between public bodies, professionals, researchers and general users. Research on identifying the role of SDI in fostering the innovation of regions and growth could meet the requirements of policy makers interested in funding initiatives and projects that could leverage such developments.

Finally, the participants discussed the effect of different *pricing policy* on the use EO data: first in the Brazilian case (section 3.16), the change from a price-based policy to a free access policy has facilitated the exploitation of Landsat data in the country and this has had an impact on the economic sector. On the other hand, cases in Australia (section 3.12) and Europe in which data are generally used by great number of users even if they are charged for (e.g. the cadastral data), indicates that the best solution is not always to make data available free of charge, particularly if the charges allow for improved maintenance and quality.

Charging the data may be seen as a cost from a different perspective: when charged for data, users tend to keep it and therefore to spend money for storing and maintaining datasets. With free data, users may avoid storing them, because they might download them again when needed.

4.2 Creation of a body of knowledge about the field

Several initiatives about the value of information have been carried out so far, as also described in the introduction. However, it was widely recognised by experts that the efforts undertaken so far have lacked of coordination, resulting in poor visibility of the research outcomes.

In absence of a solid theory, the present collections of anecdotes, case studies and applications of different methodologies carried out independently by researchers across the world, were deemed not enough. Efforts should be coordinated in order to first consolidate the state of the art and then foster it by means of suitable applications of selected methodologies on appropriate case studies.

This aspect was thoroughly discussed at the workshop, both during individual presentations and in the workgroup sessions, confirming the importance of this step to support the formation of a strong community interested in the Value of Geoinformation. The discussions gave also concrete proposals about the inclusion of this activity in the programme of research to be prepared by 2015, articulating it in different phases:

1. *Literature review*, approached by means of a meta-analysis of best practices and studies. The inclusion of grey literature should be envisaged, as well as the periodic repetition of the meta-analysis (e.g. every two years), to update with new research studies
2. All the studies collected could be gathered in a *clearinghouse*, accessible via a website, similar to the one implemented within GEOBENE and EuroGEOSS projects (<http://lyra2.felis.uni-freiburg.de/eurogeoss/>). The website should also link to other sources of information, with search capabilities.
3. Rapid development of a new body of literature, building on the existing one, by means of:
 - a. Preparing special issues in already strong journals, highly cited, with high impact factor and credibility. These may include, for example, one generic issue on "Socioeconomic Benefits of Earth Observations"; one issue in which the same EO data/systems are used in different applications (e.g. starting with Landsat, Envisat, Citizen Observers' data, the target could be 2 issues by 2015); one issue in which the same application is performed using different

EO data/systems (possible applications include FEWS, Haiti, Gulf Oil Spill, agriculture, water, disasters, health, urban, energy, migration – the target could be 3 issues by 2015); one issue applying the same methodology across problems (the methods may be selected depending on the result of the meta-analysis);

- b. supporting PhD students carrying on their research on the above mentioned studies;
- c. leveraging existing initiatives and forthcoming projects all over the world, to foster the debate about value of information;
- d. organising workshops, symposia of experts and publishing related proceedings;
- e. preparing and analysing surveys, focus groups of users and experts;
- f. composing a handbook of methodologies, as a result of all the efforts described so far;
- g. prepare a high impact paper on the state of the field.

In parallel to these “literature review” activities and case studies developments, a in depth research study on the methodologies needed to progress the field should be undertaken, that would result in the creation of a stronger community and liaisons with existing communities not only in the field of earth science, but coming from different disciplinary backgrounds.

The development of a shared definition of the concept of value of information and of an accepted scientific paradigm might be the overarching aim of this work programme, that could culminate in the creation, within relevant institutions, of “Information Impact Investigation”, that should be the equivalent of Environmental Impact Assessments.

4.3 Definition of a methodology for the estimation of EO benefits

The contributions presented at the workshop highlighted the multiplicity of methods that are currently being used by researchers to estimate the value of Earth Observation/Geographical Information. This is only a subset of the current research.

The list below summarises the methodologies being used. All experts however agreed that the identification of suitable methods may be performed only after the literature review and the meta-analysis of the studies.

Beyond the methods already mentioned in the background section (listed in *italic* below), classified after the two workshops in 2010, the following approaches have been mentioned during the workshop:

- *Price and cost-based derivation*
- *Bayesian belief network*
- *Regulatory cost-effectiveness*
- *Econometric modelling and estimation*
- *Simulation modelling and estimation*
- *transaction costs*
- *Volunteered Geographic Information*
- Performance Based Management
- Balanced Scorecard
- Meta-Knowledge Research
- Value Chain identification
- Risk Analysis
- Indicators
- Land Use Portfolio Model
- Willingness to Pay study

- Value laboratory/test bed
- Indicators
- Integrated assessment
- Business Process Modelling
- Standard Portfolio Optimisation
- Expected Value of Information measurement
- Ex-ante/ex-post Impact Assessment
- Four-step methodology of the GEOBENE project
- Economic value of productivity gains (Monash model)
- Dynamic Economic Analysis
- Expert panels (to identify case studies)
- Surveys
- Measuring Change in welfare
- General economic framework to be applied to different cases and then develop a portfolio of approaches
- Gap analysis
- Growth models with perturbation
- Multi Actor-Multi Criteria Decision-Making
- Scenario Analysis

A further research step would require the description of these methods as applied to the context of EO impact assessments (some case studies were presented within the individual presentations from participants). In addition, it would be interesting to study and map all these methodologies to see how they fit in the initial classification or if new categories should be added. Such list of methods may then be used in the applications proposed in the next section.

Particular emphasis has been given to the need of recurring to concrete, applicable methodologies and approaches focusing on SDI benefit assessment, as a piece of research that is already under development. These thoughts and proposals include:

- estimate the stage of development of SDIs, uptake, usage, trying to coordinate the already existing methods used for this purpose;
- address the lack of link to the users in the current practice of SDI assessment;
- address the problems due to lack of interoperability, for example when dealing with EU-wide policies;
- overcome the performance-based management approaches used in the public sector, due to the lack of theoretical underpinning of SDI assessments;
- the use of artificial intelligence approach/agent-based modelling may enable saying something about the quality, as attributes can be added and taken out.

4.4 Identification of suitable case studies to show the benefits of EO

Experts of the workshop reached the consensus about the fact that benefits of EO should be presented effectively to the general public and to policymakers by means of simple and intuitive case studies that may show clearly where the added value of using EO data resides, and which advantages users of whatever categories may obtain from their use. A similar purpose is realised by the “benefit matrix” proposed by Macauley (see section 3.3).

Already the presentations of the participants revealed a wide range of possible case studies and application, ranging from the impact of cities on climate change, to the coastal management, to the energy resource deployment and agriculture and food security. Despite the multiplicity of examples, it was agreed that the selection of case studies should follow determined criteria that could be initially summarised as follows:

- Multidisciplinarity;
- Engage end users who are fully involved in the case study;
- Societal relevance of information;
- Possibility to measure the Value of Information for each category of user (measure/indicators), in terms of the attributes of information;
- Transferability to other contexts and replicability over time;
- Expected societal impacts (benefits, costs);
- Temporal scale (short, medium or long term);
- Geographical scale (urban, rural, difference between developing and developed countries);
- Issue concerned large enough to be funded;
- Select cases that are complex enough but not so much;
- Look for systematic products;
- Make a case if we have or do not have information, or which is the best information we can obtain to solve a certain issue, or what happens changing level of access to determined resources;
- Consider not only specific cases but rather pilots to be applicable across different cases, with a sort of adaptive approach;
- Case studies should be simple in principle, then on the simpler ones it is possible to build more sophisticated analyses.

An effort was made to propose possible themes that, according to the experts, are of more general interest and deserve priority of examination (below not in order of priority):

1. Food security (biofuels, productivities, nitrogen contamination, desalination, climate change);
2. Water quality (nutrients, land use change, access, urban/rural, oil spills);
3. Air pollution and health (particulates, urban pollution);
4. Biodiversity management (land use change);
5. Information for society (Impact of regional SDIs);
6. Disasters (fires in Portugal, typhoons, heat waves and so on).

4.5 Outreach, dissemination, community building

The issue of dissemination of results and outreach to other communities and interested people is closely linked to the recognised difficulties in communication due to the dichotomy of scientific/policy language, highlighted in section 4.1. Therefore, main concerns during the workshops were devoted to thinking at ways to overcome this discrepancy and let people and policy makers know about research on the EO value.

First proposal was to build an identity and a precise brand for the collective activities carried out by international researchers, coordinated by a steering group to be appointed and connected by means of a website that would gather all activities and proposals. The community should have a clear communication plan, considering as key items the target audiences, the message to be delivered and how, i.e. the mechanisms, means and channels, schedules and budget. This website could host also the clearinghouse collecting the literature about the field.

Proposals followed by practical suggestions were:

- Build a joint website on what already exist, taking advantage of the proposal of GSDI Association to make their resources available through their Geographical Information Knowledge Network (GIKN, at <http://www.giknet.org>);
- A contest to create a logo and other awareness-raising material for the group and its activities;

- Schedule a showcase of the final outcomes of the programme of activities at the Milan 2015 World Expo (theme: Feeding the Planet, Energy for Life);
- Prepare a Primer on Socioeconomic Benefit (SEB) Methods for EOers, as a broad review of terminology and methodologies used in the SEB community;
- Organise webinars, lasting ~1-hour, providing on-line introductions to specific topics, for example, or EO topics for social scientists/economists, and SEB methods for EO scientists. These webinars allow people to dial in later to get and review the materials and presentations. The roll-out of the Primer could be the first webinar, while future webinars could be on case studies, ex-ante webinars, before a project starts to explain approach; and ex-post webinars, to review results and approaches; then some webinars on methodologies; one per methodology;
- Organise a series of presentations at thematic workshops and conferences.

5 FINAL CONSIDERATIONS

The experiences and perspectives presented at the workshop were deliberately heterogeneous and multi-faceted as it was recognized by the organisers that the issues addressed can only be tackled through multiple view points and disciplinary approaches.

Some contributions, more oriented at presenting case studies under development, made the audience aware of the (positive or negative) impact that data have on people and vice versa, of the challenges that humans are facing in dealing with changes in global dynamics, and of the importance to support and steer decisions by policymakers and to use existing information resources to support analysis and monitoring of the different systems. Another strand of presentations focused more on the conceptual and methodological side, giving emphasis to the need of a shared definition of the concepts of EO value, of a consistent estimation costs and benefits, and gave visibility to a wide range of suitable methods and techniques. The importance of communicating clearly and simply the benefits of EO, even if calculated with sophisticated models, making use of concrete case studies, was highlighted by all the participants. One of the results of the workshop was the identification of criteria to choose the most suitable case studies. With such evidence at hand, it was widely recognised that what is really missing is a coordination of the efforts taking place to advance this field worldwide. This coordination would strengthen and give more visibility to the individual studies, and at the same time provide an important service to people, either thematic researchers, decision makers, and in general categories of people impacted by EO.

The main suggestions were to perform good ex-ante impact assessments, monitored and supported by ex-post assessments, working for anticipating the needs and requirements of policy-makers. The approach to be followed should be multidisciplinary, including in particular strong skills in the economic field, and focus on areas that might affect huge number of users, and have social implications, thus capturing interest of decision-makers. The opportunities of EO, Public Sector Information and Spatial Data Infrastructures for innovation and growth should now be an important focus of research.

Global cooperation is needed to steer resources useful to fund this kind of projects, and adequately foster the debate about the Value of Information. In order to increase the derived benefits of the research activities, improving communication skills of scientists, to make their findings easily understandable by users and decision-makers, was highly recommended.

In conclusion, the workshop aimed to identify a programme of activities to be undertaken by 2015, differently from the previous workshops, whose outcomes were more dedicated to the conceptual issues related to the “value of data” and the methodology for measuring it. From the presentations and discussions held, it was recognized that priority should be given to the development of an accepted scientific paradigm and of a General Economic Framework to measure EO costs and benefits, the establishment of the community of

practice bringing together demanders and suppliers, support to increase in the number of researchers active in this field research group, and the showcase of concrete projects clearly communicating the benefits achieved. A follow up workshop is planned in the coming year to progress these issues further.

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Abstract

The aim of this document is to report on the workshop on “Socio-economic Benefits of Earth Observations” held at the Joint Research Centre of the European Commission, Ispra, on 11-13th July 2011. This workshop has been conducted as part of GEO Task US-09-02a: “Socio-Economic Benefits of GEO and GEOSS”, led by NASA, the International Institute for Advanced Spatial Applications (IIASA), and the Joint Research Centre of the European Commission (JRC). It was organized by these three organizations, and by the Institute of Electrical and Electronics Engineers (IEEE).

Twenty-five experts from America, Europe and Australia have gathered in Ispra to present their experience in the field of the evaluation of the benefits from Earth Observations obtained by in-situ, remote and the new citizen’s sensors.

The discussion was based on the outcomes of two previous workshops held in 2010 on the same issue, in US and in Europe. The background section presents the rationale behind the need of understanding the benefits Earth Observations, supported by several initiatives at the continental (e.g. INSPIRE Directive in Europe) and at the global (e.g. GEOSS) level.

The aim of the workshop, described in the second section of this document, was to support the development of international capabilities to determine, quantify and document the socioeconomic benefits from EO and their use, and to jointly develop a programme of activities to be followed in the next few years by the research group.

The foreseen activities of the programme were the consolidation of the body of literature in the field, the collection and analysis of suitable methodologies to assess Earth Observations’ benefits, and of evidence of benefits from existing case studies, the development of appropriate outreach initiatives, the strengthening of the existing community of researchers and the link with other communities of scientists, to set up multidisciplinary studies.

To this aim, each participant brought his/her own experience in the analysing and assessing the impacts of Earth Observation in their own field of research, generating an interesting list of multifaceted examples and case studies in which the same problem is analysed from different perspectives. Section 3 contains a summary of each presentation, which gave the elements for the subsequent discussion among experts, leading to the preliminary programme of activities. Among the several subject of discussions there were the value to be ascribed to Earth Observation data, the need of complementing ex-ante impact assessments with monitoring and ex-post evaluations, the need of clearly communicating the benefits to policy makers in order to fund research and as well to provide a service to the society. These discussion topics are summarised in section 4, describing also the view of the experts as regard possible activities for the creation of a body of knowledge about the field, for the definition of a methodology for the estimation of Earth Observations’ benefits, the criteria for selecting suitable case studies to show such benefits and proposal for outreach and dissemination activities.

As final recommendations from the workshop, priority should be given to:

- the development of an accepted scientific paradigm and of a General Economic Framework to measure EO costs and benefits;
- the establishment of a community of practice bringing together demand and supply;
- the support to increase the number of researchers active in this field research group;
- the showcase of concrete projects clearly communicating the benefits achieved.

Moreover, concrete suggestions were given aimed at developing research activities to establish a consolidated state of the art, mainly consisting in meta-analysis of existing studies and production of high-impact articles or special issues in well-recognised scientific journals.

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